Middle and South Fork Mill Creek A to Z Project
Hydrology Specialist Report
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CHAPTER I INTRODUCTION

The Three Rivers Ranger District is proposing a project on a portion of the district northeast of Colville, WA. The proposed project is known as the Middle and South Fork Mill Creek A to Z Project (Project). The National Environmental Policy Act (NEPA) analysis is being performed by Cramer Fish Sciences of Lacey, WA. A scoping packet was provided to the public on July 31, 2015 to give the public an opportunity to provide early and meaningful participation on a proposed action prior to a decision being made by the responsible official. Since that time, comments were received expressing interests and concerns with the proposed action. Many included specific items with supporting facts. In response to these comments, the proposed action was revised and alternatives were developed to address concerns that could be reconciled in the proposed action or in a revised proposed action. Alternatives were submitted on November 25, 2015 and approved in concept by the responsible official on December 22, 2015. Since then, alternatives have been refined to address direction from the responsible official and to address findings of field surveys.

This Hydrology specialist report describes hydrologic processes and the stream system within the Middle and South Fork Mill Creek Project area, and provides a detailed analysis and discussion of potential effects of proposed vegetation and fuel treatments, county and NFS road reconstruction and maintenance, temporary road construction, borrow pits, NFS road decommissioning, redefinition of pileated woodpecker core areas, fish passage structure removal and replacement, rehabilitation of user created trails, and designation of NFS roads open to all vehicles upon three indicators: 1) sediment delivery to streams; 2) streamflow regimes (i.e., peak flow, water yield, and seasonal low flow); and, 3) water quality impairment as indicated by potential change in Section 303(d) listing status.

This analysis responds to several comments that were submitted during scoping, or concerns identified by the interdisciplinary team (IDT) during scoping, analysis, and field surveys including: minimizing erosion associated with commercial harvest, shaded fuel breaks, and road management, construction and use activities, potential effects on water quality, effects on precipitation and streamflow regimes, determining the minimum road system necessary for ecological and economic sustainability of the forest, and the need to look at the cumulative effects of management activities regardless of land ownership. The analysis reported in this specialist report addresses the project design of January 20, 2016. Note: Relatively minor changes were made and incorporated into the final March 14, 2016 footprint in order to reduce potential impacts to wildlife, riparian, and other resources, including sediment delivery. These changes reduce the number of ground-skid acres and total acres logged, reduce the acreage of post-harvest fuel treatment, reduce the mileage of road to be used for log haul, and reduce the mileage of temporary road construction on both existing road grades and locations where no previous road exists. Each of these changes decreases the quantity of sediment delivery modeled and reported here, but only by relatively minor amounts. Because the sediment delivery estimates were based on the January 20, 2016 footprint, they are conservatively high, and we elected to not re-model effects that incorporate the changes per the March 14, 2016 footprint.

To assess total and cumulative effects for the action alternatives B and C, and potential effects of wildfire, the entire project area was reviewed. Several watersheds, or portions of watersheds, lie within the project area, and the potential for cumulative effects was assessed for each. Detailed, quantitative methods were applied to three 12-digit hydrologic unit code (HUC) subwatersheds
containing substantial area and/or proposed treatment units within the project area: Middle Fork Mill Creek, South Fork Mill Creek, and Camp Creek (Figure 1). All of the Middle and South Fork subwatersheds lie within the project boundary. The headwaters of the Camp Creek subwatershed lie within the project area and it flows west to the Little Pend Oreille River. Under Alternative B, 4,057 acres would receive commercial harvest and shaded fuel break treatments within the 8,319 acre Middle Fork Mill Creek subwatershed—48.8 percent of its area. 6,700 acres would receive commercial harvest and shaded fuel break treatments within the 17,749 acre South Fork Mill Creek subwatershed—37.8 percent of its area. 323 acres would receive commercial harvest and shaded fuel break treatments within the much smaller 2,599 acre Camp Creek subwatershed—12.4 percent of its area. Fewer acres would be harvested per Alternative C.

Three additional subwatersheds headwater within the project area and contain proposed treatment units: Squaw Creek (5,009 acres, 84 treated acres—1.7 percent of watershed area) per Alternative B; Amazon Creek (3,475 acres, 70 treated acres—2.3 percent of watershed area) per Alternative B; Narcisse Creek (19,092 acres, 230 treated acres—1.9 percent of watershed area) per Alternative B. Fewer acres are treated within each subwatershed per alternative C. Because little area would be affected by commercial harvest, shaded fuel break treatments, and road management activities within these subwatersheds, inventory of the road systems and area lying outside of the project boundary on state or private lands was not necessary to form sound professional opinion regarding direct, indirect, and cumulative effects. Several additional streams drain to the west off of Old Dominion Mountain within the project area. However, there are no treatment units proposed within these subwatersheds, and no road-related activities that would affect hydrologic resources and issue indicator metrics.

As described in detail later within this report, sediment delivery to streams from commercial harvest, shaded fuel break treatments, and road management and use activities—the latter being the preponderant source of sediment delivery—was modeled for all roads and treatment units within the Middle Fork Mill Creek and South Fork Mill Creek subwatersheds. However, inventory of the road systems and area lying outside of the project boundary on state or private lands was not necessary to form sound professional opinion regarding direct, indirect, and cumulative effects of sediment delivery within the remaining subwatersheds mentioned above: Camp Creek; Squaw Creek, Amazon Creek, and Narcisse Creek. Minor area proposed for logging1, limited length of road system affected, and few locations where sediment could reach streams from roads, combine in different ways within each subwatershed to indicate little change from existing sediment delivery conditions due to project activities.

Regarding streamflow response—most importantly peak flow response, which if too great can damage stream channels and fish habitat or cause flood damage—effects of proposed commercial harvest and shaded fuel break treatments on peak flows were simulated for the Middle Fork, South Fork and Camp Creek subwatersheds, as were potential effects due to past and foreseeable future harvest on other ownerships. However, peak flow response was not simulated for the Squaw, Amazon and Narcisse subwatersheds: Relatively little area would be affected per the action alternatives within these subwatersheds, and potential effects could be evaluated in relation to the simulation results produced for the Middle Fork, South Fork and Camp Creek subwatersheds, where effects would be substantially greater. A map of the Middle and South Fork Mill Creek A to Z Project area is displayed in Figure 1.

1 The term logging, when used to refer to a harvest treatment associated with the action alternatives, includes both commercial harvest and shade fuel break treatments within this Hydrology report.
CHAPTER II PLANNING GUIDANCE

Action alternatives described in Chapter II of the final EA were designed to be consistent with Forest Plan standards and guidelines and applicable laws and regulations regarding sediment, streamflow, and water quality management. A summary of this planning guidance is provided below. The effects analysis demonstrates consistency with this direction.

2.1 Forest Plan Direction

The following direction from the Colville National Forest Land and Resource Management Plan applies to hydrologic resources in the North Fork Mill Creek A to Z project area:

- Comply with Inland Native Fish Strategy (INFISH) riparian goals and objectives. INFISH (USDA 1995) provides regional interim management direction to maintain inland native fish populations and reduce potential negative impacts to aquatic habitat. The interim direction is in the form of riparian management objectives, standards and guidelines, and monitoring requirements.

- Comply with state requirements in accordance with the Federal Clean Water Act for protection of waters of the State of Washington (Washington Administrative Code, Chapters 173-201 and 202) through planning, application, and monitoring of best management practices in conformance with the Clean Water Act, regulations, and federal guidance. (USDA 1988a, p. 4-51)
- Activity resulting in suspended and bedload sediments which accelerate channel changes and/or reduce bank stability will be considered excessive. An assessment of the drainage will be done to determine cause and need for correction or mitigation.

- In watersheds where project scoping identifies an issue or concern regarding the cumulative effects of activities on water quality or stream channels, a cumulative effects assessment will be made. This will include land in all ownerships in the watershed. Activities on National Forest System lands in these watersheds should be dispersed in time and space to the extent practicable, and at least to the extent necessary to meet management requirements. On intermingled ownerships, coordinate scheduling efforts to the extent practicable. (USDA 1988a, p. 4-52)

- Revegetate cut-and-fill slopes and other large areas of disturbed soil as quickly as possible with vegetation suitable for the management goals of the area. (USDA 1988a, p. 4-52)

- Emphasize protection and improvement of soil, water, vegetation, fish, and wildlife resources while managing the riparian areas under the principles of multiple use and sustained yield. Give preferential consideration to riparian-dependent resources when conflicts among land use activities occur... (USDA 1988a, p. 4-53)

- Road construction in riparian areas will be limited to stream crossings unless determined otherwise by site-specific analysis. Numbers of stream crossings will be minimized and they will be constructed to minimize sedimentation and to allow fish passage where appropriate. (USDA 1988a, p. 4-54)


Direction is also provided by INFISH (USDA 1995) which establishes riparian goals designed to maintain or restore:

1. water quality to a degree that provides for stable and productive riparian and aquatic ecosystems;

2. stream channel integrity, channel processes, and the sediment regime (including the elements of timing, volume, and character of sediment input and transport) under which the riparian and aquatic ecosystems developed;

3. instream flows to support healthy riparian and aquatic habitats, the stability and effective function of stream channels, and the ability to route flood discharges;

4. natural timing and variability of the water table elevation in meadows and wetlands;

5. diversity and productivity of native and desired non-native plant communities in riparian zones;

6. riparian vegetation, to:
a. provide an amount and distribution of large woody debris characteristic of natural aquatic and riparian ecosystems;

b. provide adequate summer and winter thermal regulation within the riparian and aquatic zones; and

c. help achieve rates of surface erosion, bank erosion, and channel migration characteristic of those under which the riparian communities developed.

The Forest Plan also establishes desired future conditions for water quality and riparian areas:

THE FOREST IN TEN YEARS (USDA 1995, p. 4-64)

- Water quality will remain high with quantity increasing slightly. A monitoring program will be in effect to insure that water quality standards are met. Riparian areas will be stable and show some evidence of uneven-age harvest, without any resource conflicts.

THE FOREST IN FIFTY YEARS

- Riparian areas will be occupied by diverse, healthy, plant communities and water quality will consistently exceed state standards. Water quantity may increase slightly.

As directed by the Colville National Forest Land and Resource Management Plan, the project would comply with state requirements in accordance with the Federal Clean Water Act for protection of waters of the State of Washington (Washington Administrative Code, Chapters 173-201 and 202) through planning, application, and monitoring of best management practices in conformance with the Clean Water Act, regulations, and federal guidance.

In addition, the project hydrologist would be required to attest to compliance with Federal Executive Order 11988 – Protection and Management of Floodplains, and Federal Executive Order 11990 – Protection and Management of Wetlands. Executive Order 11988 provides for the protection and management of floodplains. The rules are also incorporated as BMPs in the Washington State Water Quality Standards. In addition, Executive Order 11990 provides for the protection and management of wetlands, and these rules are also incorporated as BMPs in the Washington State Water Quality Standards.

2.2 Regulatory Framework

The Federal Clean Water Act ("CWA", 33 U.S.C. § 1251 et seq.) is the foundation for surface water quality protection in the United States. The objective of the CWA is to restore and maintain the chemical, physical and biological integrity of the nation’s waters. Regarding nonpoint source pollution, including those from forest lands, Sections 208 and 319 require states to develop a process to identify, if appropriate, agricultural, silvicultural, and other categories of nonpoint sources of pollution and to set forth procedures and methods to control to the extent feasible such sources. Each state has a Nonpoint Source Management Program and Plan that directs how the state will control nonpoint source pollution. The Nonpoint Source Management Plan describes the process for identifying BMPs to control identified nonpoint sources and to reduce the level of pollution from such sources.
Once BMPs have been approved by a state, the BMPs become the primary mechanism for meeting water quality standards. Proper implementation of state approved BMPs is presumed to meet a landowner or manager's obligation for compliance with applicable water quality standards. If subsequent evaluation indicates that properly implemented BMPs are not achieving water quality standards, the state should take steps to revise the BMPs and to evaluate and, if appropriate, revise the water quality standards. Through the iterative process of monitoring and adjustment of BMPs and/or water quality standards, BMPs are expected to achieve water quality standards (EPA-823-B-94-005a (SAM 32)).

Forest Service policy for watershed management is contained in Forest Service Manual (FSM) 2500. Watershed management activities on national forests are to be implemented in accordance with the general objectives of multiple-use and the specific objectives in the Forest Plan. All management activities of other resources are to be designed to minimize short-term impacts on soil and water resources and to maintain or enhance long-term productivity, water quantity, and water quality (FSM 2503).

FSM 2532 provides policy and direction specific to water quality management on NFS lands. The objective of water quality management on NFS lands is to protect and, where needed, improve the physical, chemical, biological, and aesthetic quality of the water resource consistent with the purposes of the national forests and the national water quality goals. Approved BMPs are to be promoted and applied to all management activities as the method for control of nonpoint sources of water pollution, and for compliance with established state or national water quality goals. Applied BMPs should be based on site-specific conditions and political, social, economic, and technical feasibility.

The Federal Clean Water Act ("CWA", 33 U.S.C. § 1251 et seq.) is the foundation for surface water quality protection in the United States. Section 303(d) of the Clean Water Act establishes requirements for states and tribes to identify and prioritize water bodies that do not meet water quality standards. Every two years, states are required to prepare a list of waterbodies that do not meet water quality standards. These “impaired waters” are documented within the state’s "§303(d) list".

Through the CWA, each state is required to provide guidance and direction for the protection and restoration of water bodies (40 CFR 131.12). In Washington, the United States Environmental Protection Agency (EPA) has designated authority for compliance with the CWA to The Washington Department of Ecology. As required under the CWA, Ecology identified beneficial uses and developed water quality standards to protect beneficial uses. Designated beneficial uses established for national forests, wilderness areas, and national parks in Washington include (WAC 173-201A-200; Baldwin 2006):

- Salmon and trout spawning, core rearing and migration
- Extraordinary primary contact recreation
- Domestic, industrial, and agricultural water supply
- Stock watering
- Wildlife habitat
• Harvesting (fish, etc.)
• Commerce and navigation
• Boating
• Aesthetic values

Waters classified as Category 5 by the Washington Department of Ecology require a total maximum daily load (TMDL) study to examine pollutant sources and determine the pollutant reductions (allocations) necessary to achieve the water quality criteria. A TMDL and Water Quality Implementation Plan (WQIP) was prepared and published for the Colville National Forest for Temperature, Bacteria, pH, and Dissolved Oxygen in 2005, along with an Implementation Plan that sets load allocations that identify how much a pollutant needs to be reduced or eliminated to achieve water quality standards. The U.S. Environmental Protection Agency (EPA) decided that the report submitted by the Washington Department of Ecology lacked some required components in the dissolved oxygen and pH analysis. Therefore EPA did not approve the Dissolved Oxygen and pH portion of the TMDL; the temperature and bacteria portions of the TMDL apply. As Category 5 streams on the Colville National Forest are added to subsequent 303(d) lists, they are included in the Forest’s TMDL, WQIP, and water quality monitoring program.

Through a 2000 Memorandum of Agreement (MOA) between Region 6 of the Forest Service and the Washington State Department of Ecology (Ecology), the Forest Service is designated as the agency responsible for meeting the Clean Water Act on NFS lands. Through this MOA, the Forest Service is responsible for ensuring that all waters on NFS lands meet or exceed water quality laws and regulations, and that activities on NFS lands are consistent with protections provided in Washington Administrative Code and with relevant state and water quality requirements. The MOA recognizes the contribution of existing Forest Service direction, including the Interior Columbia Basin Ecosystem Management Project (ICBEMP), INFISH, and BMPs in meeting water quality laws and regulations, and states that the Forest Service and Ecology will collaborate to address 303(d) listings through the development of TMDLs and WQIPs. The Colville National Forest and Ecology continue to manage Clean Water Act compliance under the MOA.

CHAPTER III SEDIMENT DELIVERY

The following issue indicators are used to evaluate the effects of project activities upon sediment delivery to streams:

• Change in road density within INFISH riparian habitat conservation areas (RHCA)
• Miles of road construction and miles of reconstruction
• Miles of road decommissioned, by maintenance level
• Change in number of stream crossings
• Percent change in sediment delivery to streams in relation to natural baseline conditions
3.1 Assessment Methods

The first four issue indicators were assessed by examining the final project design, which allowed direct quantification of the metrics for these indicators. All changes may not occur in a given year or persist for the entire project life or beyond. However, the values for these parameters are displayed assuming that they apply early in the project life and persist throughout its life. These indicators were evaluated for the entire project area.

The fifth of these indicators—average annual percent change in sediment delivery to streams in relation to natural baseline conditions—provides the most meaningful indicator of potential change in sediment delivery to streams associated with the alternatives. This indicator was assessed by applying two simulation models commonly applied to NFS lands nationwide: WEPP:Road and WEPP:FuME. As indicated by its name, WEPP:Road is a simulation model that estimates road erosion and subsequent sediment delivery to streams from roads. WEPP:FuME provides estimates of sediment delivery from forest lands associated with project action alternative and with wildfire scenarios.

Sediment delivery was predicted using these modeling procedures for all roads and all commercial harvest and shaded fuel break units within the South Fork and Middle Fork Mill Creek subwatersheds. However, inventory and modeling of the road systems and area lying outside of the project boundary was not necessary to form sound professional opinion regarding direct, indirect, and cumulative effects within the Camp Creek, Squaw Creek, Amazon Creek and Narcisse Creek subwatersheds. Limited watershed area proposed for commercial harvest and shaded fuel break treatments per the project action alternatives, limited length of road system affected, and few locations where sediment could reach streams from roads, combine in various ways within each subwatershed to indicate little to no increase in sediment delivery due to proposed actions within these areas.

Summaries of the analysis methods from study plans for each of these simulation efforts follow.

3.1.1 WEPP:Road

The quantity of sediment delivered to streams as a result of erosion originating from roads within the Middle and South Fork Mill Creek A to Z Project area was estimated using the WEPP:Road model (forest.moscowfsl.wsu.edu/fswepp/). Sediment delivery was estimated for current conditions (the No Action alternative A), and for conditions based on implementation of the action alternatives B and C. Based on initial results, road segments contributing large amounts of sediment were identified as improvement opportunities. Two scenarios were then modeled for Alternatives A and B: with and without road improvement projects. Model parameterization, modeling scenarios, and interpretation of results are described in detail below.

3.1.1.1 Scope of Modeling

WEPP estimates of total quantity of sediment delivered are presented as tons per year, and as a percentage above the estimate for natural rates of erosion, for the Middle Fork and South Fork subwatersheds of the Mill Creek watershed. Analysis at this scale was selected so as to be consistent with Ecosystem Analysis at the Watershed Scale - Federal Guide to Watershed Analysis (Federal Guide) (REO 1995) and with INFISH (1995), which states that watershed analysis will follow the Federal Guide procedures. Appropriate scale of analysis is discussed at some length within the Federal Guide. The Federal Guide states that “Watershed is a useful term to associate with all areas resulting from the first subdivision of a subbasin. The watershed, then,
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is the fifth largest level in the hierarchy and is often referred to as a “fifth-field watershed.” The example given for “watershed” at page 6 of the Federal Guide is Fall Creek, a subdivision of the Middle Fork of the Willamette River, a fifth-field watershed. The combined area of the Middle Fork and South Fork subwatersheds comprises a 6th-field (12-digit HUC) subwatershed and, individually, they are 7th-field subwatersheds—meaning that they are smaller subdivisions than suggested for analysis by the Federal Guide. Furthermore, the Federal Guide states that “When planning a watershed analysis, teams should consider the size of the watershed relative to data needs, data availability, resolution, and time and resource requirements, as well as the issues to be addressed”, and “Teams generally should avoid analyzing watersheds significantly smaller than 20 square miles or larger than 200 square miles”. The South Fork area is a 27.73 square mile subwatershed. The Middle Fork area is a 13.00 square mile subwatershed.

Project treatment areas lying in subwatersheds outside of the Middle Fork and South Fork Mill Creek subwatersheds and within the Squaw Creek, Amazon Creek, and Narcisse Creek subwatersheds—none of which flow to Mill Creek—comprise only small percentages of watershed area (1.7 percent, 2.8 percent, and 2.0 percent, respectively, for Alternative B, and less for Alternative C). Road erosion and sediment delivery was field sampled and simulated on open and closed roads within the project boundary in order to form a professional opinion regarding direct and cumulative effects within these subwatersheds. As discussed later, sediment increases attributable to roads within the project area in these subwatersheds are minor, and extensive inventory of the road systems and area lying outside of the project boundary on state or private lands was not necessary to form sound professional opinion. Because proposed project activities are concentrated within the headwaters of Camp Creek, and because Camp Creek is not a tributary to either the Middle Fork or South Fork of Mill Creek sediment delivery from treatment units and roads within the project boundaries of the Camp Creek subwatershed was also modeled and compared to the estimate for natural background.

3.1.1.2 Model Parameterization

Input to the WEPP:Road model to characterize current conditions was obtained through approximately 25 man-days of field observation of design and condition of roads throughout the project area. All open roads within the project area that could be located were inventoried. Open roads for the assessment were defined as roads that could be reasonably driven with a four-wheel drive street vehicle; closed roads could not be reasonably driven because of barriers, reforestation, or heavy brush encroachment. Because closed roads typically yield little sediment delivery to streams, approximately 10 percent of closed roads were sampled. Although extensive effort was made to account for open and closed roads, some old roads are so overgrown and reverting to natural contours that they are difficult to identify, and some roads were unquestionably missed (Figure 2). Nevertheless, the road inventory and sediment delivery estimate is robust; old roads—particularly those most revegetated—typically erode very little, and yield very little to no sediment to streams. All road segments sampled for this inventory are shown in Figure 3.

As part of the field inventory, each road was divided into discrete and uniquely-numbered segments discharging to specific delivery points. Characteristics of each road segment and of the slope between the road and any downslope receiving stream specific to each road segment needed to parameterize the WEPP:Road model were recorded via electronic dataloggers. Road features recorded in the field for road segments include road prism and drainage design (e.g., outsloped, insloped, etc.), gradient and length of the segment and of the fillslope, road surfacing
characteristics (e.g., rock, native)\(^2\), and traffic characteristics (e.g., high traffic, low traffic). To facilitate this effort, a complete stream system GIS layer was developed wherein all channels exhibiting channel bed scour (i.e., stream channels) were identified. This GIS layer was developed per the Hydrology Stream Demarcation study plan, and a file containing maps with a short discussion of results is included here as Appendix A. All data, including stream delineation, were developed by project hydrologist John Gravelle.

\[\text{Figure 2. Closed National Forest System road, Middle and South Fork Mill Creek A to Z Project}\]

\(^2\) In some cases, and most notably for the South Fork county road which is poorly surfaced with rock, parts of the road were modeled with surfacing intermediate between a rocked and native earth surface. This was done by running the model for each surface type, and averaging the results.
All proposed reconstructed system and temporary roads were also modeled for each of the action alternatives based on their location and design. For this purpose, the following design features were assumed: 14-foot, native, unrutted, surfaced, and outsloped road surface; road segment length based on logical topographic breaks (e.g., streams, ridges, or maximum allowable segment length allowed by WEPP: 999 feet); road gradient based on the road location as determined from the transportation engineer field surveys and transfer of survey to geospatial data layer, and upon the underlying topography (slope) determined from digital USGS topography; fill slopes assumed to be 20 percent steeper than the underlying slope, this being assumed based on measurement of existing road fills within the area; fillslope length assumed to be 7 feet, a representative distance based on field observation of existing fills.

In many instances, temporary roads would be constructed on existing unauthorized roadbed. In this case road surface width of existing unauthorized roads that would be opened for log hauling, where field measured, was increased from existing width (used for modeling current conditions) to 14 feet, a width more representative of that necessary for log trucks.

WEPP:Road modeling also considered road conditions that would exist after implementation of proposed road construction, reconstruction, and road improvement activities. In order to develop a total sediment budget for the Middle and South Fork Mill Creek subwatersheds—and for the Camp Creek subwatershed within the project area—all remaining unsampled roads required an estimated sediment delivery yield. This sediment yield was based upon the mean estimated delivery rate (tons/mile) of sampled roads, which was then applied to unsampled road lengths to calculate an estimated sediment delivery amount for each alternative.
3.1.1.3 Modeling Scenarios

Field data for each existing and known road segment necessary for parameterization of the WEPP:Road model was input to the model in batch, and the outcome provided the estimate for the existing condition (Current Condition). The estimates for the action alternatives were based on the road plans for each alternative, standard road design characteristics assumed for planned temporary roads, and changes in levels of traffic that were anticipated to occur for each road segment. Roads produce substantially more erosion and sediment delivery when subject to heavy traffic and log truck use. WEPP:Road provides three choices for road traffic input—high, low, and no traffic—defined as follows: high traffic is generally associated with timber hauling of numerous loads of logs over the road, or with roads that receive considerable traffic during much of the year; low traffic roads are roads with administrative or light recreational use during dry weather; no traffic roads are roads with restricted or no access, and have vegetation growing on more than half of the road surface (Figure 4).

![Figure 4. Representative “no traffic” road in the Middle and South Fork Mill Creek Project area](image)

For the current condition, most roads within the project area are currently subject only to low to no traffic, although some main roads (e.g., the South Fork county road) are currently subject to heavy traffic and would remain as high traffic roads for the life of the Project, and beyond. Roads currently classed as low or no use would shift to high use for the period that they would be used for log hauling, and they would produce substantially more sediment for that period. But individual roads would not be hauled on for the entire life of the Project; a shorter period of haul would occur. Typically, operators move into an area, prepare the roads, and haul on them for a year or two, and close them up, saving prolonged maintenance costs. Accordingly, all roads,
other than certain main roads, were modeled as heavy traffic for a period of two years. Although some spur roads would serve only limited area and volume and likely would be opened and closed in a single year, the two-year assumption provides a conservatively high estimate of likely erosion and sediment delivery. Exceptions to this two-year rule were assigned to a number of main roads where relatively large areas of commercial harvest or shade fuel break would occur; these roads would be held at high for four years.

Research demonstrates that newly constructed roads erode more than old roads, all other factors being the same (WFPB 2011). WEPP:Road does not provide coefficients for new versus older road, so there is no way to directly reflect “new road” factors. However, to partially compensate for this (and to simplify the modeling) all road construction was simulated as if it would occur in the first year of the 8-year simulation and continued to contribute sediment for eight years. Likewise, following this convention, road improvement projects were simulated to occur in this same “first” year.

3.1.1.4 Interpretation of Results

Standard model output includes quantity of sediment eroded and delivered to a receiving stream segment for each road segment, and for the total road system. Quantity of sediment delivered to streams for the current condition (the No Action Alternative A) and each action alternative were then compared to the estimate for background rates of erosion for the subwatershed to develop a “percent above natural” estimate consistent with Washington State procedures for watershed analysis (WFPB 2011). This comparison was developed for the entire project area and then again for only the portion of the project area lying within the Middle Fork and, separately, for the South Fork Mill Creek subwatersheds. These “watershed” estimates, together with an estimate previously developed for the North Fork Mill Creek subwatershed, were developed to provide a basis for discussing potential impacts of sediment within the mainstem of Mill Creek downstream from the project area.

The standard Washington State procedures for calculating the road erosion increase factor is computed by dividing delivered road sediment by the background rate of erosion. Where the increase factor is less than 0.5, it receives a Low hazard rating, between 0.5 and 1.0 the hazard rating is Moderate, and when greater than 1.0 (road sediment exceeds natural sediment), the hazard rating is High. For increases of 50 percent to 100 percent (Moderate hazard), the effect of sediment in stream channels may be small, but chronically detectable (WFPB 2011). Increases exceeding 100 percent (High hazard) are likely to produce adverse effects on instream habitat characteristics and beneficial uses (i.e., they exceed Washington state water quality standards) (WFPB 2011). These calculations are important given the definition and explanation found in Forest Service Handbook 2509.22 that emphasizes impacts upon beneficial uses:

“Cumulative impacts are a change in beneficial water uses caused by the accumulation of individual impacts over time and space. Recovery does not occur before the next individual practice has begun.

EXPLANATION: The Northern and Intermountain Regions will manage watersheds to avoid irreversible effects on the soil resource and to produce water of quality and quantity sufficient to maintain beneficial uses in compliance with State Water Quality Standards. Examples of potential cumulative effects are: 1) reduced natural woody debris input to stream channels that may cause reductions in fish habitat; 2) excess sediment production that may reduce fish habitat and other beneficial uses; 3) water temperature and nutrient increases that
may affect beneficial uses; 4) compacted or disturbed soils that may cause site productivity loss and increased soil erosion; and 5) increased water yields and peak flows that may destabilize stream channel.”

In addition, INFISH states regarding riparian management goals: “The goals are to maintain or restore…stream channel integrity, channel processes, and the sediment regime (including the elements of timing, volume, and character of sediment input and transport) under which the riparian and aquatic systems developed”.

WEPP:Road estimates of the total quantity of sediment delivered to Middle Fork, South Fork, and Camp Creek streams within the project area are presented as a percentage above the estimate for the area’s natural rate of erosion and as tons per year. In addition, quantity of erosion for each road and road segment—uniquely numbered on the field data record and within the WEPP:Road input and output—were calculated to allow identification of where existing and potential future roads and road segments can be altered to reduce sediment delivery most effectively, and to identify the most cost-effective road improvement opportunities through improved maintenance (e.g., grading, surfacing, drainage), closure or decommissioning. These BMP-based measures were prescribed on a road segment-specific basis. Affected road segments were then re-modeled with WEPP:Road and the decreases in sediment delivery for the segment were documented in order to develop “with improvement” estimates. Files for examining field data inputs, the practices employed to model road segments that are to be improved in order to reduce sediment delivery, and additional WEPP:Road modeling detail, are provided in Appendix B.

WEPP:Road estimates for road sediment delivery were developed for the entire road system within the project area, and separately for the Middle Fork, South Fork, and Camp Creek subwatersheds within the project area in order to help determine effects in a watershed context. The estimates for current conditions (No Action Alternative A) are based on extensive field inventory conducted during 2015. All estimates are presented as annual average sediment delivery for a period of 8 years during the life of the Mill Creek A-Z contract. The sediment delivery modeling also assumes that National Forest System Roads would continue to be well-maintained following completion of the project. Files for examining detailed WEPP:Road summary worksheets and results are listed in Appendix C. modeling scenarios.

The documentation for the WEPP:Road model indicates that sediment delivery estimates are within +/- 50 percent of predicted values (Elliott et al. 1999b). As a result, and like for the WEPP:FuME estimates, model-predicted sediment delivery values are best used to compare relative differences between alternatives and modeling scenarios. Error estimates for the average annual sediment load are not provided by the WFPB watershed analysis manual (WFPB 2011), but this metric does help provide perspective on the relative magnitude and potential importance of a change in sediment delivery attributable to proposed activities (i.e., how much is too much).

### 3.1.2 WEPP:FuME

The WEPP:FuME model (Elliott 2005), commonly used by the Colville National Forest and other national forests, was used to estimate the quantity of sediment delivered to streams as a result of erosion associated with commercial harvest, shaded fuel breaks, and post-harvest burning. Fire lines constructed by hand or with machines may be necessary for some harvest units, and these decisions will be made on a case-by-case basis. Erosion from fire lines can occur, and it is assumed that this potential for erosion and subsequent sediment delivery is included within the WEPP:FuME post-harvest burning sediment delivery estimates.
also that delivered from wildfire scenarios that could occur under the No Action alternative. For this simulation, approximately ten percent (16 units of all commercial harvest and shade fuel break units proposed for Alternative B, and 13 units proposed for Alternative C), were randomly selected for simulation and used for comparisons. Sediment delivery for current conditions and conditions based on implementation of the action alternatives B and C were estimated.

WEPP:FuME provides an estimate of undisturbed slope sediment delivery for each commercial harvest and shaded fuel break unit (hereafter referred to as treatment units) examined, but these treatment unit-specific estimates do not provide an area-wide estimate of undisturbed slope (background) sediment delivery for the entire project area or for individual subwatersheds; for that purpose, area-wide estimates provided by the Washington procedures were applied; 11.6 tons/mi^2/yr, Middle Fork; 16.0 tons/mi^2/yr South Fork and Camp Creek. These values were also used for the WEPP:Road calculations. This allows the WEPP:FuME and WEPP:Road results to be aggregated consistently to develop cumulative watershed effects estimates of percent sediment delivery increase over natural for Alternative A with wildfire, and for alternatives B and C, for each subwatershed. Total sediment delivery for the modified proposed action Alternative B for the Middle and South Fork subwatersheds, together with total sediment delivery predicted for the North Fork proposed action, provides an estimate of cumulative sediment delivery to the main stem of Mill Creek immediately downstream from the project area at the confluence of the South and North Forks.\footnote{The Middle Fork is tributary to the South Fork.}

Application of INFISH riparian habitat conservation areas (RHCAs), as well as additional undisturbed area lying between treatment units and receiving streams, limits sediment delivery; in many cases, treatment units lie several hundred feet from the nearest stream. Moreover, slopes within the project area generally are not very steep, averaging only about 25 percent, which minimizes surface erosion and sediment movement, and increases the effectiveness of buffer areas.

Based on road density (miles/miles^2), WEPP:FuME also provides estimates of road sediment delivery for each treatment unit sampled. However, these values are not used in the calculation of road sediment delivery; instead, the more reliable and precise values yielded by WEPP:Road are used.

All factors required by the WEPP:FuME model input screen, including acres to be treated by commercial harvest or shaded fuel breaks, fuel management treatment, slope within the treatment area, and characteristics of the stream buffer (the area between the treatment units and downslope streams) for each unit selected for simulation—were developed from the project footprint GIS spatial data. General soil textural class within each unit was identified by the project soil scientist\footnote{Only broadcast burn acres were included within our modeling. Because pile and burn acres are scattered throughout units, we considered it highly unlikely that erosion from these areas would translate downslope as sediment delivery to streams. Similarly, sediment delivery would not be affected by the application of slashing, chipping, crushing, mowing, or mulching treatments because these treatments would not be expected to increase the extent and pattern of soil exposure and disturbance such that material amounts of soil erosion would occur and/or such that eroded material would be transported to streams.}
based on existing soil survey information (Donaldson and DeFrancesco 1982) and digital terrain data; the silt loam textural class representative of volcanic ash topsoils was used for all units.

The buffer width used for the WEPP:FuME modeling for each treatment unit selected for modeling includes the entire untreated distance lying between the treatment unit and the nearest stream. This distance represents the area available to trap sediment that may originate as erosion from within the treatment unit. This buffer distance includes the INFISH RHCA width applied to the nearest stream lying downslope from the unit, plus any additional untreated distance lying between the unit and the INFISH RHCA buffer. Because "treatment units" often included cable and ground machinery-logged subunits, subunits were then randomly selected for measurement of input data (e.g., hillslope gradient, hillslope length, buffer gradient, buffer length). Only the undisturbed distance lying between the subunit and the nearest stream was used for buffer characteristics: If other subunits - typically cable-logged area - were positioned downslope from the selected subunit, this distance was not included as part of the buffer. Using these procedures, buffer distances varied from 75 feet (unit 246 in both alternatives B and C) up to 1,000 feet—the maximum buffer distance allowed by WEPP:FuME, even though measured distance was often greater for several units.

Simulation output (tons of sediment delivered to streams per square mile per year) reported by the WEPP:FuME model runs for each treatment (commercial harvest or shaded fuel break) unit modeled are reported individually and averaged for each modeling scenario. Copies of all WEPP:FuME model runs are included in the file listed in Appendix D.

The WEPP:FuME estimates of average annual sediment delivery from treatment units were developed for the entire project area, and separately for the Middle Fork, South Fork, and Camp Creek subwatersheds, as annual rates of sediment delivery for a time period corresponding to the estimated return interval for wildfire for the project area: 100 years was used for the return interval of high-severity fires. 30 years was used for the commercial harvest and shaded fuel break treatment return interval. Files for examining detailed WEPP:FuME results are listed in Appendix E.

The documentation for the WEPP:FuME model does not provide estimates of model accuracy. As a result, and like for the WEPP:Road estimates, model-predicted sediment delivery values are best used to compare relative differences between alternatives and modeling scenarios. In this regard, we note that using WEPP:FuME we were unable to differentiate the amount of erosion and sediment delivery predicted from ground-based and cable logging units, even though it is well known that cable logging produces substantially less soil disturbance and erosion than does ground-based logging (Rice and Datzman 1981). Moreover, WEPP:FuME does not seem to account for the substantial decrease in ground disturbance that occurs with use of modern feller-buncher based logging systems as opposed to tractor-based systems that were more commonly used years ago. For these reasons, we expect that the WEPP:FuME erosion and sediment delivery estimates for project activities are considerably higher than may actually occur.

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6 Mill Creek slope and terrain data was generated from 1 arc second Shuttle Radar Topography Mission (SRTM) imagery compiled by the USDI Geologic Survey department (USGS 2010). Accuracy of SRTM data is 10-meter root mean square error or less, as specified in the STS-99 mission specifications.

7 INFISH RHCA buffer widths applied to the project area based on a local site-potential tree height of 110 feet are, at minimum, 55 feet slope distance for seasonally flowing or intermittent streams (1/2 site-potential tree height), 150 feet slope distance for permanently flowing non-fish bearing streams, and 300 feet slope distance for fish-bearing streams.
3.2 Current Conditions

Stream systems and their natural sediment regimes are controlled by the landscape morphology (geomorphology) that they form within. Continental glaciation, most recently approximately 18,000 years ago, affected virtually the entire project area at all elevations. Slopes at upper elevations have been scoured, leaving steep slopes below rounded peaks and ridges. Subsoils underlying volcanic ash topsoils within the project area have formed from metamorphic and igneous rocks. Geologically old metamorphic rocks (predominantly stratified micaceous phyllite, argillite, and siltite), are found at upper elevations in the Middle Fork Mill Creek subwatershed and the eastern parts of the South Fork Mill Creek subwatershed. Subsoils formed from these formations tend to have substantial clay component and moderate erodibility. Quartzites form most of Dominion Mountain. They weather slowly and tend to form soils with low erodibility. South of the South Fork are found granitic rocks that form sandy soils with moderate to high erodibility. Deep, well-drained glacial outwash and moraine (drift) deposits overlie the base rocks throughout the project area at lower elevations. Landtype association (Davis et al. 2004) and geology (Joseph 1990) mapping provide good depiction of this glacial aftermath (Figure 5). Landtype Associations are defined by general topography, geomorphic process, surficial geology, soil, potential natural vegetation, and local climate. Collectively, these features become diagnostic factors that control or strongly influence biotic distribution, hydrologic function, and ecological functions, including natural disturbance regimes.

![Figure 5. Landtype Associations](image-url)

Nearly the entire project area was burned by wildfire in the 1920s, much of it severely and with stand replacement. Extensive area of the project area was then logged 30 or more years ago, mostly using ground-based log skidding systems that caused extensive soil disturbance and that
may have added substantial sediment to streams. However, based on the observations and results reported within the soil specialist report, there is little to no evidence of currently-occurring erosion and sediment delivery associated with past logging on NFS lands.

Dense stands and closed canopy conditions are now common within the project area, particularly on NFS lands. These stands are also at an increased risk of high-severity fire again due to the large amount and distribution of fuels. Also, an extensive network of logging roads was constructed within the project area—mostly 40 or more years ago—and these roads added considerable sediment to stream systems historically. Some road segments, particularly where they are located adjacent to streams, continue to erode and add considerable sediment to streams.

### 3.2.1 Background Sediment Delivery

Because many of the following sediment delivery comparisons are made in relation to natural background sediment yields, the derivation of these estimates is provided here. The Washington State watershed analysis procedure for estimation of natural sediment yield is calculated as:

\[
\text{Annual erosion volume (m}^2/\text{yr)} = \text{stream length (m)} \times 2 \times \text{soil depth (m)} \times (1 - \text{fraction of coarse fragments}) \times \text{soil creep (m/yr)}^8.
\]

For the South Fork Mill Creek subwatershed, based on calculations and observations, this yields:

\[
89683 \text{ m} \times 2 \times 2 \times (1 - 0.25) \times 0.001 \text{ m/yr} = 269 \text{ m}^2/\text{yr annual erosion volume.}
\]

Assuming bulk density of the soil to be \(\sim 1.5\), sediment yield in metric tons/yr is equal to \(1.5 \times 269 = 403.6\).

Dividing 403.6 by the South Fork Mill Creek drainage area of 27.73 mi\(^2\), the calculated background rate equates to 14.6 metric tons/ mi\(^2\)/yr. With the conversion rate of 0.907 metric tons = 1.0 tons, the resulting calculated background rate is 16.0 tons/mi\(^2\)/yr.

For the Middle Fork, the calculations yield 11.6 tons/mi\(^2\)/yr.

### 3.2.2 Current Sediment Delivery

Three management activities may currently cause erosion that results in sediment delivery to streams within the project area: roads, recent logging, and livestock grazing. However, observation of road conditions, road sediment runoff to the stream network, instream sediment deposits, conditions within logging units and their location in relation to streams, and streambank and channel conditions indicate that the primary source of anthropogenic sediment is roads. Severe erosion of some stream-adjacent roads currently occurs and is documented—as are road erosion and sediment delivery conditions throughout the project area—within this report. Consistent with the literature directly relevant to the project area (Tepp 2002; Hoelscher et al. 1993; Zaroban et al. 1997), and with the results reported in the Soil specialist report (i.e., that very few survey locations evidenced erosion), only incidental sediment delivery from logged areas was observed during the extensive hydrology and soil surveys conducted for the project.

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\(^8\) For these calculations, stream length was measured from the stream demarcation geospatial layer and multiplied by 2 (two stream sides) per WFPB procedures; 2 meters was used effective soil depth and percent coarse fragments was estimated based on observation of road cutbank exposures and from soil survey information; 0.001 m/yr for soil creep rate was selected as suggested by WFPB procedures for gentle slopes.
area. Livestock grazing in some riparian areas was observed, but denuded streambanks and channel damage related to grazing is very limited and, though not quantified, was judged to be minor in a watershed sediment budgeting context.

Average annual sediment delivery produced by the existing road system is predicted using WEP:Road and totals 16.0 tons/year, or about 10.7 percent above natural background rates for the Middle Fork Mill Creek subwatershed. Sediment delivery was evaluated and modeled for the road system irrespective of ownership (i.e., roads on non-NFS roads were evaluated consistent with the procedures described in sections 3.1.1.2 through 3.1.1.4). For the South Fork subwatershed, average annual sediment delivery produced by the existing road system is predicted to total 61.9 tons/year, or about 13.9 percent above natural background rates. For Camp Creek, only limited area and road system mileage lie within the project boundary; we did not attempt to inventory and model sediment delivery for the roads on private lands comprising the remainder of the subwatershed. However, in order to place sediment delivery predicted for project activities in perspective for the Camp Creek subwatershed, sediment delivery produced by the existing road system within the project area was inventoried and modeled, and compared to the estimate of the natural background sediment yield for the subwatershed. Existing average annual sediment delivery from roads within the project area of Camp Creek is predicted to total 0.27 tons/year, or about 0.4 percent above natural background rates for the subwatershed. Note: Because we also did not attempt to verify the stream network for the Camp Creek subwatershed, as we did for the South and Middle Forks, here we applied the natural background estimate developed for the adjacent South Fork: 16.0 0 tons/mi²/yr. These existing sediment delivery quantities are relatively low in a watershed context. As noted in section 3.1.1.4, where increases in sediment delivery are 50 percent to 100 percent above natural the effect of sediment in stream channels may be small but chronically detectable (WFPB 2011). The modeled increases estimated for South Fork Mill Creek, Middle Fork Mill Creek, and Camp Creek (13.9 percent, 10.7 percent, and 0.4 percent, respectively) would be expected to be undetectable except at locations immediately downstream from problem road locations and sources.

3.3 Management Prescriptions

The following management prescriptions were developed pursuant to the planning guidance outlined above and based on findings of current conditions outlined above in order to avoid or minimize sediment delivery to streams. The effects analysis presented in the next section is based on the implementation of these management prescriptions and other design elements described in Chapter II of the final EA.

3.3.1 Road Improvement Projects

Road improvement activities were designed for 13 locations and a total of 13 miles of road (Figure 6, Table 1, Table 2, and Table 3). Currently, these road segments deliver large quantities of sediment to streams. These road segments need improvement irrespective of proposed project treatments and the increased log truck traffic that would occur on some of them. Some of these improvement activities involve road decommissioning of NFS roads.

Heavy log truck traffic normally increases erosion and sediment delivery. However, the road improvement projects more than compensate for this effect. Combined with the heavy traffic effect, four projects are estimated to decrease sediment delivery from the current condition by 9.57 and 10.87 tons/year for Alternatives B and C, respectively, within the Middle Fork subwatershed, 5.7 and 6.5 percent less than delivered by the road system in its current condition. Similarly, for the South Fork subwatershed, four road improvement projects are estimated to
decrease sediment delivery from the current condition by 26.04 and 27.01 tons/year for Alternatives B and C, respectively, 5.2 and 5.3 percent less than delivered by the road system in its current condition. For the Camp Creek subwatershed, the one road improvement project identified mitigates the effect of heavy traffic; essentially no net change occurs within the project area of this subwatershed. These projects were selected based on field observation and the results of the modeling because the targeted roads segments delivered large amounts of sediment and because there is good opportunity to substantially reduce this. However, although the modeling was limited to this select list of the best sediment reduction opportunities, there are other road segments where additional projects could be implemented, albeit with less benefit. In practice, many of these areas would be addressed during project implementation as roads are maintained in advance of log hauling. In this regard, our estimate through modeling of sediment reduction limited to road improvement projects likely is conservatively low.

Figure 6. Proposed road improvement projects, Alternatives B and C
### Table 1. Road improvement projects: Middle Fork

<table>
<thead>
<tr>
<th>SegmentID</th>
<th>Road Number</th>
<th>Miles</th>
<th>Treatment</th>
<th>Existing delivery (tons/yr)</th>
<th>Improved delivery (tons/yr)</th>
<th>Existing (2015) Maintenance Level</th>
<th>Expected Post-project Maintenance Level</th>
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<tr>
<td>M1</td>
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### Table 2. Road improvement projects: South Fork

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Middle and South Fork Mill Creek A to Z Project

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Table 3. Road improvement projects: Camp Creek

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<th>Treatment</th>
<th>Existing delivery (tons/yr)</th>
<th>Improved delivery (tons/yr)</th>
<th>Reduction from existing (tons/yr)</th>
<th>Existing (2015) Maintenance Level</th>
<th>Expected Post-project Maintenance Level</th>
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<td>0.01</td>
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3.3.2 Temporary Road Construction

Construction of temporary roads within RHCA’s was minimized by the project interdisciplinary team by eliminating certain initially-proposed road locations, changing logging prescriptions to cable or helicopter logging, finding alternative road locations, and by eliminating parts or all of initially-proposed treatment units that would have required road construction within RHCA’s.

3.3.3 Mitigation Measures

The Best Management Practices for Water Quality Management on National Forest System Lands document (USDA 2012), dated April 2012, would be applied to mitigate effects of the proposed Project, minimizing adverse impacts to aquatic habitat caused by county and NFS roads while serving the needs of the public and providing for management of the National Forest:

a. Road-7. Stream Crossings. The intent of this BMP is to avoid or minimize adverse effects to soil, water quality, and riparian resources when constructing, reconstructing, or maintaining temporary and permanent waterbody crossings. Measures to be applied regarding Road-7 addressing fish passage structure replacements or removals and other culvert replacements, installations and removals are further described in the Fisheries design elements, below.

b. Road-10. Equipment Refueling and Servicing. The intent of this BMP is to avoid or minimize adverse effects to soil, water quality, and riparian resources from fuels, lubricants, cleaners, and other harmful materials discharging into nearby surface waters or infiltrating through soils to contaminate groundwater resources during equipment refueling and servicing.
activities. Equipment will be refueled and serviced at locations that would be determined at
the pre-work meeting during project implementation.

c. Chem-3. Chemical Use Near Waterbodies. The intent of this BMP is to avoid or minimize
the risk of chemical delivery to surface water or groundwater when treating areas near
waterbodies. BMPs for noxious weed treatment designed to avoid adverse effects on soils,
water quality and riparian resources are described in the 2005 Preventing and Managing
Invasive Plants EIS and ROD and the 1998 Integrated Noxious Weed Treatment EA, and
would be applied to all areas receiving chemical treatment.

d. Chem-5. Chemical Handling and Disposal. The intent of this BMP is to avoid or minimize
water and soil contamination when transporting, storing, preparing, and mixing chemicals;
cleaning application equipment; and cleaning or disposing chemical containers. BMPs for
noxious weed treatment designed to avoid adverse effects on soils, water quality and riparian
resources are described in the 2005 Preventing and Managing Invasive Plants EIS and ROD
and the 1998 Integrated Noxious Weed Treatment EA, and would be applied to all areas
receiving chemical treatment.

e. Veg-2. Erosion Prevention and Control. The intent of this BMP is to avoid or minimize
adverse effects to soil, water quality, and riparian resources by implementing measures to
control surface erosion, gully formation, mass slope failure, and resulting sediment
movement before, during, and after mechanical vegetation treatments. Erosion from treatment
units would be prevented and controlled through application of standard erosion control
BMPs—including water barring and development of slash mats on skid trails, through
application of INFISH RHCAs adjacent to all streams, and by specifying skid trail and
yarding corridor width and spacing during pre-sales meetings.

f. Veg-4. Ground-Based Skidding and Yarding Operations. The intent of this BMP is to avoid
or minimize adverse effects to soil, water quality, and riparian resources during ground-based
skidding and yarding operations by minimizing site disturbance and controlling the
introduction of sediment, nutrients, and chemical pollutants to waterbodies. Erosion from
treatment units would be prevented and controlled through application of standard erosion
control BMPs, including water barring and development of slash mats on skid trails, through
application of INFISH RHCAs adjacent to all streams, and by specifying skid trail and
yarding corridor width and spacing during pre-sales meetings.

g. Veg-5. Cable and Aerial Yarding Operations. The intent of this BMP is to avoid or minimize
adverse effects to soil, water quality, and riparian resources during cable and aerial yarding
operations by minimizing site disturbance and controlling the introduction of sediment,
nutrients, and chemical pollutants to waterbodies. Erosion from treatment units would be
prevented and controlled through application of standard erosion control BMPs, including
water barring and development of slash mats on skid trails, through application of INFISH
RHCAs adjacent to all streams, and by specifying skid trail and yarding corridor width and
spacing during pre-sales meetings.

h. Veg-6. Landings. The intent of this BMP is to avoid or minimize adverse effects to soil,
water quality, and riparian resources from the construction and use of log landings. Whole-
tree log landings would be designated outside of INFISH RHCAs; decking areas may be
utilized on a case-by-case basis along existing main-line roads within INFISH RHCAs where
sediment delivery concerns are evaluated and considered null.
i. **Veg-7. Winter Logging.** The intent of this BMP is to avoid or minimize adverse effects to soil, water quality, and riparian resources from winter logging activities. Winter logging would be accomplished primarily with cut-to-length systems, and performed with a combination of 8 inches of frozen soil and snow pack. See Soils design elements below.

j. **Veg-8. Mechanical Site Treatment.** The intent of this BMP is to avoid or minimize adverse effects to soil, water quality, and riparian resources by controlling the introduction of sediment, nutrients, chemical, or other pollutants to waterbodies during mechanical site treatment. Mechanical site treatment would rarely if ever be used, but would follow the same erosion control BMPs as logging operations.

k. **Fire-2. Use of Prescribed Fire.** The intent of this BMP is to avoid or minimize adverse effects of prescribed fire and associated activities on soil, water quality, and riparian resources that may result from excessive soil disturbance as well as inputs of ash, sediment, nutrients, and debris. A prescribed burn plans would be developed for each treatment area. The use of hand-built and machine-built firelines around burn areas would be on a case-by-case basis in consideration of slope, access, adjacency to other prescribed burn areas, and estimated fire behavior. Prescribed burn units and fire control lines would be designed to fall outside INFISH RHCAs. Burn plans would avoid burning in INFISH RHCAs.

In addition, the following mitigation measures would be employed to monitor compliance with BMPs and effectiveness of temporary road decommissioning:

1. Road decommissioning surveys would be conducted for all temporary roads, and for all NFS roads proposed for decommissioning. Monitoring would use BMP evaluation effectiveness forms and selective use of photopoints to document effectiveness. CNF staff would develop necessary forms, and would complete the forms for each road immediately following its decommissioning, and annually for a sufficient number of years until effectiveness of the decommissioning measures has been sufficiently established. BMP effectiveness forms would document implemented management measures, that roads have been blocked to prohibit traffic effectively, that roads are becoming revegetated, and that sediment delivery is limited to incidental amounts. Corrective measures would be applied as needed to ensure that objectives of road decommissioning are achieved. The intent of road decommissioning monitoring is to ensure that decommissioning measures are implemented effectively.

m. **Compliance monitoring** would be conducted to ensure that site-specific BMPs are implemented as specified in the National Best Management Practices for Water Quality Management on National Forest System Lands document dated April 2012, that INFISH standards and guidelines are followed, and that implementation is consistent with Forest Service obligations per the Memorandum of Agreement between the USDA Forest Service, Region 6 and the Washington State Department of Ecology for meeting responsibilities under federal and state water quality laws. The intent of this design element is to protect water quality and beneficial uses, to meet or exceed the requirements of the CWA and state water quality laws and regulations as contained in the state Forest Practices Rules (WAC 222), to insure compliance with Washington Administrative Code 173-201A-200, and to ensure that project activities and best management practices are avoiding or minimizing adverse impacts to water quality.
3.4 Environmental Consequences

This section provides a detailed analysis of potential effects of the No Action and action alternatives related to sediment delivery to streams. This analysis addresses the effects of the modified proposed action and alternatives, summarized in Chapter II of the final EA and described in detail in resource specialist reports. The analysis considers implementation of design elements described in Chapter II intended to avoid or minimize adverse impacts to aquatic habitat caused by county and NFS roads while serving the needs of the public and providing for management of the National Forest.

3.4.1 Literature Review

Timber management has been shown to affect sediment supply (Lisle and Hilton 1992). Forest management activities—principally logging, roads, and wildfire—affect soil erosion and sediment delivery (stream sedimentation) processes, with potential adverse effects upon stream morphology and fish habitat. Undisturbed forest soils of the Northwest are normally well protected by surface organic materials and a thick organic surface soil horizon and, as a result, raindrop splash and overland flow of water and associated surface erosion rarely occurs (Dunne and Leopold 1978). Several studies conducted throughout the Northwest demonstrate that soil disturbance associated with forest harvesting and fuel treatment operations can result in erosion and subsequent delivery of eroded materials (sediment) to streams (Robichaud et al. 2010).

However, these studies also demonstrate that erosion and sediment delivery caused by harvesting only occurs where 1) soils are disturbed, 2) disturbed soils are subject to overland flow and particle detachment (erosion), and 3) eroded soil particles (sediment) are transported to streams without deposition onto the forest floor (Fredriksen 1970; Megahan et al. 1980; Hetherington 1976).

Erosion of forest soils associated with modern logging practices is limited. In an assessment of soil disturbance associated with thinning of several logging units conducted on the Colville National Forest, Tepp (2002) observed no soil erosion. Forest practice audits in Idaho have found that hillslope erosion does not contribute sediment to streams except where disturbance has occurred adjacent to streams, which in most cases has occurred only where activities were found to have been out of compliance with the Idaho Forest Practices Rules (Hoelscher et al. 1993; Zaroban et al. 1997). Thinning operations without yarding have small, short-lived impacts on runoff and sediment production, even when operations extend over large areas (Robichaud et al. 2010).

In contrast to soil erosion associated with modern logging practices, erosion and sedimentation associated with forest roads is common. Most sediment delivery from roads occurs at stream crossings or along road segments located near streams with insufficient buffer zone width. In general, approximately one-third or less of total road system mileage has been found to contribute sediment to stream systems; conversely, two-thirds or more of road system mileage did not contribute (Bilby et al. 1989; Bowling and Lettenmaier 1997; La Marche and Lettenmaier 1998; and Wemple et al. 1996). Annual delivery of surface erosion sediment to streams from a given road segment can vary from zero to tens of tons, depending on such factors as the specific delivery route (stream crossing vs. gully vs. discharge to hillslope), contributing road length, road gradient, hillslope gradient, road surfacing, and road traffic intensity (Elliot et al. 1999a; Haupt 1959; WFPB 2011). Effectiveness of road design and maintenance practices is documented by a number of reports, including: Burroughs and King (1989); WFPB (2011); Burroughs and King (1985).
INFISH RHCAs prevent soil disturbance and erosion from occurring within them and, if of sufficient width, are effective at trapping sediment that originates as erosion from upland sources beyond their boundaries. A study of sediment filtering effectiveness of buffer strips as a function of distance in areas of high to moderate soil erodibility in central Idaho demonstrated that 80 percent to 95 percent of sediment from road fills and road drainage structures is trapped and prevented from reaching streams within a buffer width of 75 feet. This trapping efficiency increases to nearly 100 percent at 150 feet. Sediment delivery at distances of 300 feet or more rarely occurs (Megahan and Ketcheson 1996; Ketcheson and Megahan 1996; King 1979). In a study conducted in finer-textured soils of the Oregon Coast Range, Brake et al. (1997) found that sediment transport distances were substantially shorter than those found in Idaho. Effectiveness of buffers at preventing sediments originating from logging from reaching streams is further documented by several studies conducted throughout the northwest (Hoelscher et al. 1993; Hetherington 1976; Zaroban et al. 1997).

Although sediment movement downslope below harvest-caused soil disturbance has not been documented in the same manner as it has from road sources, Ketcheson and Megahan (1996) report that sediment from diffuse road drainage sources (rock drains and road fills) in highly erodible granitic soils had only a 10 percent chance of moving more than 47 feet. Since sediment transport distance increases with the volume of eroded material discharged from the eroding surface (Megahan and Ketcheson 1996; Ketcheson and Megahan 1996; King 1979), transport distances for eroded materials originating from harvest-caused soil disturbance would likely be even less, because soils are normally less disturbed, less compacted, and drainage more dispersed than for roads.

Culvert replacement can cause short-term increases in sediment yield. Foltz et al. (2008) report that an average of approximately 0.1 tons of sediment was delivered to streams during culvert replacement in highly erodible soils of the Idaho Batholith and Border Zone metamorphic geologies of central Idaho. Foltz also reports that the preponderance of delivery occurs within the first few hours of instream work, and that sediment delivery from culvert replacement is small compared to that from culvert plugging and failure due to lack of maintenance or obsolescence. Shapiro (1985) reviews several additional studies wherein the volume of sediment that would be delivered to streams in the event of culvert failure would be on the order of three to four times greater than that associated with culvert replacement.

Wildfire and prescribed fire can increase runoff, erosion and sediment yield. The major factor that determines the effects of burning on runoff and erosion is the amount of disturbance to the surface organic material (duff) that protects the underlying mineral soil (Robichaud et al. 2010). Sediment yields following low severity-prescribed fire have been found to be an order of magnitude less than those following high-severity prescribed fire in Idaho, and far less than occurs following high-severity wildfire, with low sediment yield reported following low burn severity prescribed fire (Robichaud et al. 2010).

High-severity wildfires increase runoff and erosion rates by two or more orders of magnitude, while low and moderate-severity burns have much smaller effects (Robichaud et al. 2010). Severe and continuing surface erosion, landslides, and channel erosion associated with wildfire was reported in central Idaho following a severe wildfire in 1994 (Figure 7 and Figure 8), with rates of landsliding in these burned areas as much as five times higher than the maximum rate of landsliding observed in similar managed areas. Severity and rate of sediment delivery was also reported to be much greater within burned areas (PWA 1998). Robichaud and Brown (1999) discuss the results from studies that document accelerated erosion rates following wildfire, with
erosion rates of as much as 7 times greater than for unburned areas. Severe sediment increases were documented by Potts et al. (1985) in watersheds with steep slopes and metamorphic parent materials following large wildfires, with maximum annual sediment production increases of 284 percent over natural yields.

Figure 7. Severe erosion in granitic soils following wildfire, South Fork Boise River watershed, 1994
3.4.2 Direct and Indirect Effects

3.4.2.1 Analysis Indicators

**Sediment Delivery to Streams:** This metric represents tons of sediment delivery to streams from all project erosion source activities (commercial harvest, shaded fuel breaks, and post-harvest burning, road activities, stream crossing culvert installations and removals), and is presented in relation to existing conditions, and in relation to an estimate of natural background sediment delivery within three subwatersheds: Middle Fork Mill Creek; South Fork Mill Creek; Camp Creek. Short-term effects to sediment delivery were evaluated for the period of time during project activities. Long-term effects were evaluated for the period of time after completion of project activities.

**Change in Road Density within RHCA (miles of new RHCA road / square miles of RHCA):**
This metric indicates potential for detrimental impacts within riparian zones, including increased sediment delivery

**Miles of Road Constructed:** This metric indirectly indicates potential for increased sediment delivery due to road construction.

**Miles of Road Reconstructed:** This metric indirectly indicates potential for reductions in sediment delivery due to road reconstruction.

**Miles of Road Decommissioned:** This metric indirectly indicates potential for reductions in sediment delivery due to road decommissioned.
Number of New Stream Crossings: This metric indicates potential for short-term sediment delivery due to construction of stream crossings.

3.4.2.2 Alternative A – No Action

3.4.2.2.1 Methods and Assumptions
The No Action alternative would not implement ground-disturbing activities that have the potential to deliver sediment to streams; there would be no commercial harvest or shaded fuel break treatments, road construction or reconstruction, development of borrow pits or culvert installation or removal. Therefore, there would be no direct and indirect effects of the No Action alternative on sediment delivery on NFS lands in the project area relative to the current condition. Existing previously-approved activities on NFS lands and roads would continue within the project area—including wildfire suppression, road maintenance, noxious weed control, livestock grazing, dispersed camping, use of Little Twin Lakes Campground, motorized vehicle use on designated roads and trails, use of groomed snowmobile trails, non-motorized recreation, and firewood gathering.

Current conditions in the project area were determined through methods described above. For existing conditions – Alternative A, no action - nearly all sediment delivery currently occurring is associated with roads, and was estimated based on field inventory and application of the WEPP:Road model (Elliott et al. 2009), and as occurs naturally as estimated using the Washington Watershed Analysis procedures (WFPB, 2011), described in detail earlier within this chapter. Erosion and sediment delivery from past logging of Colville National Forest lands was not observed, and sediment delivery from private and state lands may occur in some specific locations, but based on field observation of conditions, was assumed to be limited. The WEPP:FuME model (Elliott 2005) was applied to develop an estimate of erosion and sediment delivery that could occur in the event of severe wildfire.

3.4.2.2.2 Direct and Indirect Effects
Selection of the no action alternative would not affect current road conditions and sediment delivery to streams or any of the other issue indicators. Erosion from roads is the dominant source of sediment delivery for the existing condition within the project area. Poor maintenance of some NFS roads is currently causing rutting and obstruction of roadside ditches and culverts in some areas; further deterioration of these roads could accelerate sediment delivery. Areas disturbed by past logging, and old inactive road and landing surfaces, currently deliver little sediment to streams beyond what occurs naturally. No new logging or road-related activities—the latter being the preponderant source of anthropogenic sediment delivered to streams—would occur under this alternative.

Without vegetation treatment, the chances for stand-replacing wildfire and uncharacteristic disturbance increases, directly increasing the potential for detrimental impacts on stream and fish habitat attributable to increased soil erosion and mass wasting. High-severity wildfire would destroy forest floor litter and duff to expose soils, create water repellent conditions, and destroy soil aggregates (Robichaud and Brown 1999). Fine sediment levels in streams would increase, at least temporarily, and streambanks and beds may shift and become less stable as channels adjust to increased sediment regimes.

Based on the sampled treatment units, the WEPP:FuME annual average estimate of sediment delivery attributable to areas affected by wildfire (based on a 100-year fire interval) averages 140
percent above natural background for 100 years. In reality, effects may be much more concentrated in time. Based on stand inventory data and review of 1943 photos obtained by the project hydrologist from the National Archives for this purpose, the majority of the project area appears to have been severely burned by a high-severity wildfire that occurred in 1929. However, for modeling purposes, and to simplify comparisons to modeling performed for the North Fork Mill Creek project and the cumulative effects analysis, high-severity fire affecting 40 percent of the Middle South Fork project area was assumed for the wildfire scenario.

**Middle Fork Mill Creek Subwatershed**

For Middle Fork Mill Creek, sediment delivery due to surface erosion following high-severity fire affecting 40 percent of watershed area and distributed as an annual average for 100 years increases by 84.2 tons/year, 51 percent above the existing condition (Figure 9), and 66 percent above natural (Figure 10). Wildfire scenarios where a greater portion of the watershed is burned or with a shorter return interval would yield substantially greater increases in sediment delivery. These more extreme scenarios were not modeled.  

![Figure 9. Sediment delivery to streams above existing conditions, Alternative A, if wildfire affected 40 percent of the Middle Fork Mill Creek subwatershed](image)

Kate Day, East Zone Hydrologist for the Colville National Forest, points out that other wildfire effects models predict much larger short-term of sediment delivery where the forest floor and soil is burned than do these WEPP:FuME estimates.
Three Rivers Ranger District, Colville National Forest

Figure 10. Sediment delivery to streams above natural background conditions, Alternative A, if wildfire affected 40 percent of the Middle Fork Mill Creek subwatershed

South Fork Mill Creek Subwatershed
For South Fork Mill Creek, sediment delivery due to surface erosion following severe wildfire affecting 40 percent of watershed area and distributed as an annual average for 100 years increases by 248.5 tons/year, 49 percent above the existing condition (Figure 11), and 70 percent above natural (Figure 12).
Figure 11. Sediment delivery to streams above existing conditions, Alternative A, if wildfire affected 40 percent of the South Fork Mill Creek subwatershed.

Figure 12. Sediment delivery to streams above natural background conditions, Alternative A, if wildfire affected 40 percent of the South Fork Mill Creek subwatershed.
Camp Creek Subwatershed

Project activities are also concentrated within the headwaters of the Camp Creek subwatershed. Road sediment delivery for the entire Camp Creek subwatershed was not estimated because most of the road system and delivery sources lie outside the project area and on private lands. However, sediment delivery from roads within the project area was inventoried and estimated to total 0.27 tons/year and 0.4 percent over natural for the Camp Creek subwatershed.

Sediment delivery due to surface erosion following severe wildfire affecting 40 percent of watershed area and distributed as an annual average for 100 years increases by 36.4 tons/year, 56 percent above the existing condition (Figure 13), and 56 percent above natural (Figure 14).

![Figure 13. Sediment delivery to streams above existing conditions, Alternative A, if wildfire affected 40 percent of the Camp Creek subwatershed](image-url)
3.4.2.3 Alternatives B and C – Action Alternatives

Project effects on sediment delivery mostly occur from road systems, commercial timber harvest and shaded fuel break treatments, post-harvest fuel treatment and, to a much smaller degree, culvert installation and removal. Effects from commercial harvest and shaded fuel breaks; fish passage structure replacement and removal; road maintenance, reconstruction, decommissioning, and road improvement projects; and the effects of heavy traffic are addressed in Commercial Harvest Effects. Additional effects on sediment delivery could occur through actions common to both action alternatives not associated with commercial harvest. These are addressed in the Effects Common to Both Action Alternatives section.

3.4.2.3.1 Commercial Harvest Effects

Alternative B – Modified Proposed Action

With selection of Alternative B, approximately 11,483 acres would receive commercial harvest and shaded fuel break treatments designed to increase forest health, resiliency to insects and disease, and decrease susceptibility to high-severity wildfire. Potential detrimental effects of severe wildfire upon soils would decrease, as would sediment delivery increases. In addition, the modified proposed action includes planned road maintenance for about 18 miles of county roads and 70 miles of NFS roads (including culvert replacement), reconstruction of county and NFS road at various locations in the project area, a net increase of approximately 0.8 miles of NFS road associated with reconstruction of NFS road 9411175, about 8 miles of NFS road decommissioning, about 13.3 miles of temporary road construction on new road bed, and removal or replacement of 17 fish passage structures.
Presentation of the first four of the five sediment delivery issue indicators for the project area follows. The 5th indicator; sediment delivery to streams, that being quantified via estimates provided by the WEPP:Road and WEPP:FuME modeling, provides the most meaningful information about the delivery of sediment to streams that could occur from proposed project activities and is presented by watershed in the following sections.

Change in Road Density within RHCA (miles of new RHCA road / 7.06 square miles of RHCA):

- NFS roads: -0.32
- Temporary road on existing road bed: 0.02
- Temporary road where no road bed currently exists: 0.11

Miles of Road Constructed:

- NFS road: 0.8 (road realignment project)
- Temporary road on existing road bed: 5.7
- Temporary road where no road bed currently exists: 13.3

Miles of Road Reconstructed:

- NFS road: 3.2
- County road: 1.1

Miles of Road Decommissioned:

- Maintenance Level 1 NFS road: 4.09
- Maintenance Level 2 NFS road: 2.10
- Maintenance Level 3 NFS road: 1.45

Number of New Stream Crossings:

- NFS road: 3
- Temporary road: 4

**Middle Fork Mill Creek Subwatershed Sediment Delivery**

Compared to the existing condition for the Middle Fork Mill Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative B due to road-related activities (road construction; increased log truck traffic; culvert installations, replacements, and removals; and road improvement projects) is predicted to decrease by 9.6 tons/year, a 59.6 percent decrease from the sediment delivery from roads per the existing condition. However, 3.2 tons/year additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks is predicted, and 5.6 tons/year attributable to fuel treatment is predicted. Short-term, net sediment delivery under Alternative B is predicted to total 15.3 tons/yr, 0.7 tons (4.7 percent) less than for the existing condition (Figure 15).
In actuality, the sediment increases and decreases predicted to occur with project implementation would occur as a sequence through time. It can be reasonably assumed that road maintenance and most of the road reconstruction and improvement projects within a given area would first be completed, followed immediately by commercial harvest and shaded fuel breaks and hauling, with burning occurring months to a year or two later. The outcome from this sequence would be immediate benefit of the maintenance, reconstruction and improvements, followed by the effects of commercial harvest, shaded fuel breaks, hauling, and post-harvest burning. Nevertheless, during and immediately following commercial harvest, shaded fuel breaks, hauling and post-harvest burning, a short-term increase in sediment delivery may occur within some subwatersheds tributary to the Middle and South forks of Mill Creek.

Sediment delivery increases associated with hauling are for practical purposes limited to the time during which log haul occurs; when hauling ceases, road traffic reverts from “high” back to its pre-hauling condition. The preponderance of sediment increases that may occur due to commercial harvest, shaded fuel breaks, hauling, and post-harvest burning are likely to be limited to the time during which logging occurs to a few years following. On the other hand, sediment delivery decreases attributable to improvements made in the road system are likely to persist throughout the remaining life of the Project, and for many years thereafter.

Comparison to natural background rates of erosion is most useful for examining cumulative effects within watersheds and allows comparison to the Washington Watershed Analysis Manual threshold where it is stated that the effect of sediment delivery to stream channels greater than 50 percent above natural may be chronically detectable within streams (WFPB 2011).
For Middle Fork Mill Creek, sediment delivery due to surface erosion associated with Alternative B is predicted to decrease by 0.8 tons/year, 0.5 percent less than for the existing condition (Figure 16). The estimated increase above natural background for Alternative B, including the road improvement projects, totals 15.3 tons/year, 10.2 percent above natural background rates (Figure 17), and less than the 10.7 percent increase estimated for the current condition (see discussion for Alternative A). Of this 15.3 tons/year, 6.5 tons/year is attributable to roads (existing roads, realigned roads, temporary roads, increased traffic, and culverts) and 8.8 tons/year (5.8 percent above natural) is attributable to commercial harvest, shaded fuel breaks, and post-harvest burning (Figure 17).

![Graph showing sediment delivery to streams above natural background for the existing condition and for Alternative B, Middle Fork subwatershed](image)

**Figure 16.** Predicted sediment delivery to streams above natural background for the existing condition and for Alternative B, Middle Fork subwatershed
Figure 17. Predicted sediment delivery to streams above natural background, Alternative B, for the Middle Fork subwatershed

**South Fork Mill Creek Subwatershed Sediment Delivery**

Compared to the existing condition for the South Fork Mill Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative B due to road-related activities (road construction; increased log truck traffic; culvert installations, replacements, and removals; and road improvement projects) is predicted to decrease by 26 tons/year, a 42.1 percent decrease from the sediment delivery from roads per the existing condition. However, 8.9 tons/year additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks, and 5.2 tons/year attributable to fuel treatment is also predicted. Short-term, net sediment delivery under Alternative B is predicted to total 49.9 tons/yr, 12 tons (19.4 percent) less than the existing condition (Figure 18).
For South Fork Mill Creek, sediment delivery due to surface erosion associated with Alternative B is predicted to decrease by 12 tons/year, 2.4 percent less than for the existing condition (Figure 19). The estimated increase above natural background for Alternative B, including the road improvement projects, totals 49.9 tons/year, 11.2 percent above natural background rates (see Figure 17), and less than the 14.0 percent increase estimated for the current condition (see discussion for Alternative A). Of this 49.9 tons/year, 35.8 tons/year is attributable to roads (existing roads, new roads, increased traffic, and culverts) and 14.1 tons/year (3.2 percent above natural) is attributable to commercial harvest, shaded fuel breaks, and post-harvest burning (Figure 20).

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10 Includes culvert installation and removal effects
Figure 19. Predicted sediment delivery to streams above natural background for the existing condition and for Alternative B, South Fork Mill Creek subwatershed.

Figure 20. Predicted sediment delivery to streams above natural background conditions, Alternative B, for the South Fork subwatershed.
Sediment Delivery Within the Project Area of the Camp Creek Subwatershed

Compared to the existing condition within the project area of the Camp Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative B due to road-related activities (road construction; increased log truck traffic; culvert installations, replacements, and removals; and road improvement projects) is predicted to increase by 0.5 tons/year above the existing condition. 0.7 tons/year of additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks, and 0.2 tons/year attributable to fuel treatment, is also predicted. Short-term, net sediment delivery under Alternative B is predicted to total 1.4 tons/year, 1.1 tons greater than for the existing condition. Compared to natural background conditions (Figure 21), sediment delivery with Alternative B is predicted to be 2.1 percent over natural (0.4 percent existing, plus 1.7 percent from project activities). Given that this increase is less than 50 percent, the effect of this sediment delivery would be expected to be undetectable within stream channels (WFPB 2011).

![Figure 21. Predicted sediment delivery to streams above natural background for the existing condition and for Alternative B, Camp Creek subwatershed within the project area](image)

Although not reported, short-term increases in sediment delivery to some smaller tributary streams could occur due to road-related activities and due to commercial harvest, shaded fuel breaks, and fuel treatments. However, even in the absence of road improvements, sediment delivery from project activities would be low, and it is unlikely that they would exceed 50% of natural background levels in any given stream reach; the effect of this sediment delivery would be expected to be undetectable within stream channels (WFPB 2011). With proposed improvements implemented prior to other ground-disturbing activities and timber haul, increases above 50% of natural background would not occur within subwatersheds where these project activities are located. Further, compliance monitoring would be conducted to ensure that site-specific BMPs are implemented as specified in the National Best Management Practices for Water Quality.
Management on National Forest System Lands document dated April 2012, that INFISH standards and guidelines are followed, and that implementation is consistent with Forest Service obligations per the Memorandum of Agreement between the USDA Forest Service, Region 6 and the Washington State Department of Ecology for meeting responsibilities under federal and state water quality laws. The intent of this design element is to protect water quality and beneficial uses, to meet or exceed the requirements of the CWA and state water quality laws and regulations as contained in the state Forest Practices Rules (WAC 222), to insure compliance with Washington Administrative Code 173-201A-200, and to ensure that project activities and best management practices are avoiding or minimizing adverse impacts to water quality.

**Alternative C – Commercial Harvest without New Road Construction**

With selection of Alternative C, approximately 9,358 acres would receive commercial harvest and shaded fuel break treatments designed to increase forest health, resiliency to insects and disease, and decrease susceptibility to widespread wildfire. Potential detrimental effects of severe wildfire upon soils would decrease, as would sediment delivery increases. In addition, the modified proposed action includes planned road maintenance for about 18 miles of county roads and 70 miles of NFS roads (including culvert replacement), reconstruction of county and NFS road at various locations in the project area, a net increase of approximately 0.8 miles of NFS road associated with reconstruction of NFS road 9411175, about 8 miles of NFS road decommissioning, about 13.3 miles of temporary road construction on new road bed, and removal or replacement of 17 fish passage structures. Presentation of the first four of the five sediment delivery issue indicators for the project area follows. The 5th indicator; sediment delivery to streams, that being quantified via estimates provided by the WEPP:Road and WEPP:FuME modeling, provides the most meaningful information about the delivery of sediment to streams that could occur from proposed project activities and is presented by subwatershed in the following sections.

Change in Road Density within RHCA (miles of new RHCA road / 7.06 square miles of RHCA):

- NFS road: -0.32
- Temporary road: 0

Miles of Road Constructed:

- NFS road: 0.8 (road realignment project)
- Temporary road: 0

Miles of Road Reconstructed:

- NFS road: 3.2
- County road: 1.1

Miles of Road Decommissioned:

- Maintenance Level 1 NFS road: 4.09
- Maintenance Level 2 NFS road: 2.10
- Maintenance Level 3 NFS road: 1.45

Number of New Stream Crossings:

- NFS road: 3
Temporary road: 0

**Middle Fork Mill Creek Subwatershed Sediment Delivery**

Compared to the existing condition for the Middle Fork Mill Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative C due to road-related activities (road construction; increased log truck traffic; culvert installations, removals, and replacements; and road improvement projects) is predicted to **decrease** by 10.9 tons/year, a 67.6 percent decrease from the sediment delivery from roads per the existing condition. 2.7 tons/year of additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks, and 3.9 tons/year attributable to fuel treatment, is also predicted. Short-term, net sediment delivery under Alternative C is predicted to total 11.7 tons/yr, 4.4 tons (27.2 percent) **less** than for the existing condition (Figure 22).

![Figure 22. Predicted sediment delivery to streams from commercial harvest, shaded fuel breaks, post-harvest burning, and roads Alternative C, Middle Fork Mill Creek subwatershed, in relation to existing conditions](image)
Sediment delivery increases associated with hauling is for practical purposes limited to the time during which log haul occurs; when hauling ceases, road traffic reverts from “high” back to its pre-hauling condition. The preponderance of sediment increases that may occur due to commercial harvest, shaded fuel breaks, hauling and post-harvest burning are likely to be limited to the time during which logging occurs to a few years following. On the other hand, sediment delivery decreases attributable to improvements made in the road system are likely to persist throughout the remaining life of the Project, and for many years thereafter.

Comparison to natural background rates of erosion is most useful for examining cumulative effects within watersheds and allows comparison to the Washington Watershed Analysis Manual threshold where it is stated that the effect of sediment delivery to stream channels greater than 50 percent above natural may be chronically detectable within streams (WFPB 2011).

For Middle Fork Mill Creek, sediment delivery due to surface erosion associated with Alternative C is predicted to decrease by 4.4 tons/year, 2.6 percent less than for the existing condition (Figure 23). The estimated increase above natural background for Alternative C, including the road improvement projects, totals 11.7 tons/year; 7.8 percent above natural background rates (Figure 24), and less than the 10.7 percent increase estimated for the current condition (see discussion for Alternative A). Of this 11.7 tons/year, 5.2 tons/year is attributable to road-related activities (existing roads, new roads, increased traffic, and culverts) and 6.5 tons/year (4.3 percent above natural) is attributable to commercial harvest, shaded fuel breaks, and post-harvest burning (Figure 24).

![Figure 23. Predicted sediment delivery to streams above natural background for the existing condition and for Alternative C, Middle Fork subwatershed](image-url)
Figure 24. Predicted sediment delivery to streams above natural background, Alternative C, for the Middle Fork subwatershed

**South Fork Mill Creek Subwatershed Sediment Delivery**

Compared to the existing condition for the South Fork Mill Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative B due to road-related activities (road construction; increased log truck traffic; culvert installations, replacements, and removals; and road improvement projects) is predicted to **decrease** by 27 tons/year, a 43.6 percent decrease from the sediment delivery from roads per the existing condition. 6.8 tons/year additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks, and 3.6 tons/year attributable to fuel treatment, is also predicted. Short-term, net sediment delivery under Alternative C is predicted to total 45.3 tons/yr, 16.6 tons (26.8 percent) **less** than for the existing condition (Figure 25).
Figure 25. Predicted sediment delivery to streams from commercial harvest, shaded fuel breaks, post-harvest burning, and roads Alternative C, South Fork Mill Creek subwatershed, in relation to existing conditions.

For South Fork Mill Creek, sediment delivery due to surface erosion associated with Alternative C is predicted to decrease by 16.6 tons/year, 3.3 percent less than for the existing condition (Figure 26). The estimated increase above natural background for Alternative C, including the road improvement projects, totals 45.3 tons/year; 10.2 percent above natural background rates (Figure 27), and less than the 14.0 percent increase estimated for the current condition (see discussion for Alternative A). Of this 45.3 tons/year, 34.9 tons/year is attributable to roads (existing roads, new roads, increased traffic, and culverts) and 10.4 tons/year (2.3 percent above natural) is attributable to commercial harvest, shaded fuel breaks, and post-harvest burning (Figure 27).
Figure 26. Predicted sediment delivery to streams above natural background for the existing condition and for Alternative C, South Fork Mill Creek subwatershed.

Figure 27. Predicted sediment delivery to streams above natural background conditions, Alternative C, for the South Fork subwatershed.
Sediment Delivery Within the Project Area of the Camp Creek Subwatershed

Compared to the existing condition within the project area of the Camp Creek subwatershed, average annual sediment delivery during the life of the Project under Alternative C due to road-related activities (road construction; increased log truck traffic; culvert installations, replacements, and removals; and road improvement projects) is predicted to increase by 0.5 tons/year above the existing condition. There would also be 0.4 tons/year additional sediment delivery increases attributable to commercial harvest and shaded fuel breaks, and 0.1 tons/year attributable to fuel treatment. Short-term, net sediment delivery under Alternative C is predicted to total 1.0 tons/year, 0.6 tons greater than for the existing condition. Compared to natural background conditions (Figure 28), sediment delivery with Alternative C would be 1.4 percent over natural (0.4 percent existing, plus 1.0 percent from project activities). Given that this increase is less than 50 percent, the effect of this sediment delivery would be expected to be undetectable within stream channels (WFPB 2011).

![Figure 28. Predicted sediment delivery to streams above natural background for the existing condition and for Alternative C, Camp Creek subwatershed within the project area](image)

Although not reported, short-term increases in sediment delivery to some smaller tributary streams could occur due to road-related activities and due to commercial harvest, shaded fuel breaks, and fuel treatments. However, even in the absence of road improvements, sediment delivery from project activities would be low, it is unlikely that they would exceed 50% of natural background levels in any given stream reach, and the effect of this sediment delivery would be expected to be undetectable within stream channels (WFPB 2011). With proposed improvements implemented prior to other ground-disturbing activities and timber haul, increases above 50% of natural background would not occur within subwatersheds where these project activities are located. Further, compliance monitoring would be conducted to ensure that site-specific BMPs
are implemented as specified in the National Best Management Practices for Water Quality Management on National Forest System Lands document dated April 2012, that INFISH standards and guidelines are followed, and that implementation is consistent with Forest Service obligations per the Memorandum of Agreement between the USDA Forest Service, Region 6 and the Washington State Department of Ecology for meeting responsibilities under federal and state water quality laws. The intent of this design element is to protect water quality and beneficial uses, to meet or exceed the requirements of the CWA and state water quality laws and regulations as contained in the state Forest Practices Rules (WAC 222), to insure compliance with Washington Administrative Code 173-201A-200, and to ensure that project activities and best management practices are avoiding or minimizing adverse impacts to water quality.

3.4.2.3.2 Effects Common to Both Action Alternatives

Road Reconstruction and Maintenance

Road maintenance is planned for about 18 miles of county roads and 70 miles of NFS roads under Alternatives B and C. Road maintenance is necessary for most roads prior to use for log hauling, and would be expected to decrease sediment delivery in many instances. However, these same roads would experience increased log truck traffic which substantially increases erosion and sediment delivery. The effects of increased traffic are included within the WEPP:Road estimate of sediment delivery for roads for each alternative. We did not attempt to model the effects of road maintenance. However the effects of specific road improvement projects designed to reduce sediment delivery were modeled and were presented in Table 1, Table 2, and Table 3.

Culvert installation and removal impacts associated with road reconstruction and maintenance would be short-term and would immediately be countered by the risk of far larger additions of sediment that would occur in the event culverts fail, washing all or parts of the immediate road prism into streams. Many culverts scheduled for replacement are undersized, are failing, are partially blocked, pose barriers to fish passage, or otherwise partially dysfunctional. As many as 12 culverts may be installed or removed (replacements are considered as both a removal and an install) within the Middle Fork subwatershed. As many as 55 culverts may be installed or removed within the South Fork subwatershed. One culvert will be replaced within the Camp Creek subwatershed. No additional culverts would be replaced outside of these three subwatersheds. Culvert installation and removal is expected to add approximately 0.1 tons of sediment per structure (Foltz et al. 2008). Action involving installation and removal is expected to have short-term impacts on sediment delivery of approximately 0.1 tons per replacement structure below the crossing sites (Foltz et al. 2008), but the long-term benefits would be a reduction in risk of erosion and sediment production and delivery associated with culvert failure resulting in washout of all or part of the local road prism. Improvement of hydraulic conditions often results in less backwatering upstream of the site and less scour downstream. Overall effects would not materially impact project effects on sediment delivery.

Development of borrow pits

As many as 15 borrow pits may be developed. Under Alternative B, five pits would be expansions of existing borrow pits and ten new borrow pits would be developed. Under Alternative C, five existing borrow pits would be expanded and five new pits would be developed. Development of borrow pits would create some degree of erosion, but because they are located away from streams, sediment delivery from borrow pits to streams is unlikely.
**NFS road decommissioning**
As many as 7.7 miles of system roads may be decommissioned under alternatives B and C. In some cases because of poor road location (e.g., where located adjacent to streams), road decommissioning is proposed specifically to reduce sediment delivery. Sediment delivery decreases due to road decommissioning are included within the WEPP:Road estimate of decreased sediment delivery for roads for each alternative.

**Shaded fuel breaks**
Shaded fuel breaks may be developed on as many as 462 acres under alternatives B and C. These harvest-like activities are assumed to create erosion and sediment delivery no different than those modeled with WEPP: FuME for Commercial Harvest Treatments. Because this activity is similar to commercial harvest activities, direct and indirect effects of shaded fuel breaks are addressed in Commercial Harvest Effects.

**Precommercial thinning**
Precommercial thinning activities are planned on as many as 836 acres. Because precommercial thinning would be done by hand and without ground-disturbing machinery, no erosion and sediment delivery would occur.

**Redefinition of pileated woodpecker core area**
Redefinition of pileated woodpecker core area may affect as many as 190 acres. Redefinition of pileated woodpecker core area would not disturb soils and increase sediment delivery.

**Fish passage structure replacement and removal**
As many as 17 culverts may be replaced or removed to improve fish passage. Fish passage structure replacement and removal is expected to add approximately 0.1 tons of sediment per replacement structure (Foltz et al. 2008). Actions involving culvert replacement and removal to improve fish passage are expected to have short-term impacts on sediment delivery of approximately 0.1 tons per replacement structure below the crossing sites (Foltz et al. 2008), but the long-term benefits would be a reduction in risk of erosion and sediment production and delivery associated with culvert failure resulting in washout of all or part of the local road prism. Improvement of hydraulic conditions often results in less backwatering upstream of the site and less scour downstream. Overall effects would not materially impact project effects on sediment delivery.

**Rehabilitation of areas impacted by user-created trails**
As many as 2.8 acres would be affected by rehabilitation of user-impacted trails. Rehabilitation of areas impacted by user-created trails may accelerate recovery of disturbed surfaces subject to erosion, and could result in small decreases in sediment delivery. Effects would be minor, and no attempt was made to model them.

**Designation of NFS roads open to all vehicles**
NFS roads 7018000 and 9411130 would be re-designated from open only to highway vehicles to open to all vehicles. Designation of NFS roads open to all vehicles would not create additional soil disturbance, erosion or sediment delivery. Monitoring of off-road vehicle use would be conducted to ensure that unauthorized use of NFS lands adjoining these roads would not occur and result in unintended sediment delivery.
**Tree Planting**

Within five years after VDT/VRH harvests, planting is proposed in created openings to achieve, along with natural regeneration, desired stocking levels and species composition. Tree planting would be done without soil-disturbing machinery, and erosion and sediment delivery would not occur.

### 3.4.3 Cumulative Effects

Cumulative effects related to sediment delivery are the incremental impacts of an alternative when added to the effects of other past, present, and reasonably foreseeable future actions. See Appendix A of the final EA for a summary of all past, present, and reasonably foreseeable future actions in the project area.

**Geographic Scope** - The cumulative effects analysis area includes the Middle and South Forks of Mill Creek, the North Fork of Mill Creek, Grevit Creek, and Mill Creek immediately downstream of the confluence of the South and North Forks of Mill Creek. The headwaters of the Camp Creek subwatershed that lies within the project area comprises a small part of Little Pend Oreille River basin; therefore, it is not included in the cumulative effects analysis area. Although parts of the Clugston Creek, Onion Creek, Squaw Creek, Amazon Creek and Narcisse Creek subwatersheds are within the project area boundaries of the North Fork Mill Creek A to Z Project and Middle and South Fork Mill Creek A to Z Project, only small areas of their watersheds lie within the project boundaries and only small parts of these subwatersheds are treated under the action alternatives; they are not included in the cumulative effects analysis area.

**Temporal Scope** - The timeframe for cumulative effects analysis is thirty years into the future, approximately the timeframe anticipated for re-entry into the project area to address changes in stand structure resulting from proposed treatments and stand development. Cumulative effects on water quality in the future would mostly occur through commercial harvest and shaded fuel break treatments, road construction, rural residential use, dispersed recreation, and cattle grazing.

**Past Actions** - Nearly the entire cumulative effects analysis area was regenerated by stand-replacing fires in the 1920s. Wildfire likely led to increases in sediment delivery to streams in the cumulative effects analysis area (see analysis of sediment delivery under a wildfire scenario in the analysis of direct and indirect effects of Alternative A on sediment delivery). Past activities occurring in the cumulative effects analysis area that may have had additional effects on sediment delivery include wildfire suppression, timber harvest, road construction, recreation use, livestock grazing, and conversion of forest lands to pasture and other non-forest land uses (e.g., rural residential development and transmission line corridor construction). The effects of wildfire and past activities on sediment delivery in the cumulative effects analysis area subwatersheds are reflected in the existing conditions for sediment delivery.

**Present and Reasonably Foreseeable Actions** - Wildfire suppression, timber harvest, road construction, rural residential use, transmission line corridor maintenance, and livestock grazing are ongoing and are anticipated to be the reasonably foreseeable future actions in the cumulative effects analysis area. Actions in the project area are documented in Appendix A of the final EA. Actions outside the project area are described below. Cumulative effects on sediment delivery during this timeframe would mostly occur through vegetation treatments. While wildfire suppression would continue to occur, it is not possible to predict when and where these actions may overlap with the effects of the proposed Project.
Within the project area, a review of Washington Forest Practice applications (WaDNR 2016) on state and private lands in the project area indicates ongoing and future plans for 274 acres of uneven-aged harvest, 213 acres of even-aged harvest, and less than 0.1 miles of new road construction. Effects of timber harvest and road construction on state and private lands in the project area would be mitigated by Washington State Forest Practice Rules designed to limit adverse impacts to sediment delivery from these activities. Livestock grazing would continue to occur on two NFS grazing allotments, as well as on non-NFS lands. Dispersed recreation would continue, with limited impacts to sediment delivery. The footprint of rural residential development is not expected to increase in the cumulative effects analysis area subwatersheds. There are no other known planned major developments or land use changes that would alter disturbance patterns in the project area.

Outside the project area, the Colville National Forest is implementing the North Fork Mill Creek A to Z Project which involves commercial harvest, fuel hazard reduction, precommercial thinning, road reconstruction and maintenance, and habitat restoration at levels comparable to that under the modified proposed action, on a per-acre basis. A review of Washington Forest Practice Applications indicates that timber harvest and road construction on state and private lands are also anticipated to occur at levels comparable to those in the Middle and South Fork Mill Creek A to Z Project area. Effects of timber harvest and road construction on state and private lands outside the project area would be mitigated by Washington State Forest Practice Rules designed to limit adverse impacts to sediment delivery from these activities. Livestock grazing on NFS lands would continue on one grazing allotment, as well as on non-NFS lands within the North Fork Mill Creek subwatershed. The footprint of rural residential development and transmission line corridors is not expected to increase. There are no other known planned major developments or land use changes that would alter disturbance patterns in the cumulative effects analysis area.

Effects of timber harvest and road construction on state and private lands in the cumulative effects analysis area would be mitigated by Washington State Forest Practice Rules. Based on a per-acre comparison of the effects of timber harvest and road construction from the modified proposed action, additional timber harvest and road construction activity that may occur on non-NFS land within the cumulative effects analysis area would be expected to increase sediment delivery less than 1 percent. Sediment delivery from roads within the North Fork Mill Creek and Grevit Creek subwatersheds is expected to decrease through road maintenance, reconstruction, and realignment projects under the North Fork Mill Creek A to Z Project. The effects of culvert and fish passage structure replacement—short-term sediment delivery—are expected to be minor through use of BMPs. Sediment delivery from logged areas within the North Fork Mill Creek subwatersheds is expected to remain a minor component of total sediment delivery due to implementation of erosion and sediment control BMPs, including INFISH requirements, such as those proposed for the Middle and South Fork Mill Creek A to Z Project. An overall net decrease in sediment delivery is anticipated long-term as a result of implementing the Project.

In the Middle and South Fork Mill Creek subwatersheds, current grazing levels would continue under Allotment Management Plans (AMPs) that incorporate new management practices, standards, and mitigations based on current laws, regulations, and policies of the Forest Service. Allotment Operating Instructions would continue to be used to adaptively manage on a year-to-year basis within the intent of the AMPs and in response to monitoring results. Existing range improvements would continue to be maintained. Several range improvement projects would continue to be implemented and maintained in order to harden stream crossings to reduce cattle damage and allow restoration of riparian areas. In the North Fork Mill Creek subwatershed, the total amount of sediment introduced into stream systems as a result of ongoing livestock grazing
of the 33 cow/calf pairs on the North Fork Mill, Strauss, and Rodgers pastures is expected to continue to decrease as grazing management allows riparian vegetation to become reestablished and any overgrazed areas to recover. Sediment delivery from livestock grazing on non-NFS lands in the cumulative effects analysis area is not expected to change.

3.4.3.1 Alternative A – No Action

Under the No Action alternative, sediment delivery would be approximately 10.7 percent (Middle Fork Mill Creek subwatershed) to 13.9 percent (South Fork Mill Creek) above natural for the project area due to erosion and delivery from roads (including all roads irrespective of ownership)—with very little delivery currently occurring from other sources within the area—and would be expected to occur at or near current rates as a result of ongoing and future foreseeable actions. Sediment delivery in the North Fork Mill Creek subwatershed under the North Fork Mill Creek A to Z Project would decrease by about 1 percent in the short-term due to rehabilitation of localized “hot spots”. In the long-term, after project completion, sediment delivery would decrease by about 65 percent once project-related log haul traffic ceases—and with continued maintenance of NFS roads. Sediment delivery from activities on non-NFS lands would increase by less than 1 percent over existing conditions. Cumulative effects downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek within the cumulative effects analysis area would therefore be expected to decrease. Overall, effects of the No Action alternative without wildfire, combined with the effects of other past, present, or reasonably foreseeable future actions, would produce no adverse cumulative effect related to sediment delivery. Fuel build-up and stand conditions have developed that increase the likelihood of large, stand-replacing wildfire. Large portions of the cumulative effects analysis area would be converted to early stand structural stages, irrespective of ownership. Within the Middle and South forks of Mill Creek, sediment delivery with wildfire would increase approximately 50 percent above existing conditions in both subwatersheds. Effects of activities in the North Fork Mill Creek subwatershed would have no net effect on sediment delivery in the near-term, but would decrease sediment delivery by about 65 percent long-term. Cumulative effects downstream within the mainstem Mill Creek are computed as area-weighted averages of the effects within the upstream subwatersheds. Therefore, the effects of the No Action alternative with wildfire would result in short-term and long-term increases in sediment delivery downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek.

3.4.3.2 Alternative B – Modified Proposed Action

Under the modified proposed action, sediment delivery would decrease by about 4.7 percent (Middle Fork Mill Creek subwatershed) and 19.4 percent (South Fork Mill Creek subwatershed) in the short-term due to rehabilitation of localized “hot spots”. In the long-term, after project completion, sediment delivery would decrease by more than 40 percent (South Fork Mill Creek subwatershed) to 60 percent (Middle Fork Mill Creek subwatershed) once project-related log haul traffic ceases—and with continued maintenance of NFS roads. Under the North Fork Mill Creek A to Z Project, sediment delivery would decrease by about 1 percent in the short-term in the North Fork Mill Creek subwatershed due to rehabilitation of localized “hot spots”. In the long-term, after project completion, sediment delivery would decrease by about 65 percent once project-related log haul traffic ceases—and with continued maintenance of NFS roads. Timber harvest on state and private lands within the cumulative effects analysis area would continue. Sediment delivery would be limited through compliance with the Washington State Forest Practice Rules, as described above.Livestock grazing would continue on NFS lands, with improved grazing practices that are intended to improve riparian conditions, stream habitat, and water quality. Livestock grazing along private lands would also likely continue, with unknown
effects on stream habitat. Downstream from the project boundary within the mainstem of Mill Creek, cumulative sediment delivery effects potentially could occur due to the combined sediment delivery to the Middle Fork, South Fork, and the North Fork. However, a net short-term sediment delivery decrease is predicted for each of these subwatersheds, and therefore would also be predicted to occur within Mill Creek. Since there would be no added negative effect on sediment delivery to Mill Creek from the modified proposed action to the effects of other past, present or reasonably foreseeable future actions, cumulative effects would not occur. A net decrease in sediment delivery would result from Alternative B; a positive effect. Over the long-term (post-Project) there also would be a reduction in sediment delivery within the Middle Fork and South Fork Mill Creek subwatersheds, and within the mainstem Mill Creek watershed.

3.4.3.3 Alternative C – Commercial Harvest without New Road Construction

Under Alternative C, sediment delivery would decrease by about 27.2 percent (Middle Fork Mill Creek subwatershed) and 26.8 percent (South Fork Mill Creek subwatershed) in the short-term due to rehabilitation of localized “hot spots”. In the long-term, after project completion, sediment delivery would decrease by more than 40 percent (South Fork Mill Creek subwatershed) to 70 percent (Middle Fork Mill Creek subwatershed) once project-related log haul traffic ceases—and with continued maintenance of NFS roads. Under the North Fork Mill Creek A to Z Project, sediment delivery would decrease by about 1 percent in the short-term in the North Fork Mill Creek subwatershed due to rehabilitation of localized “hot spots”. In the long-term, after project completion, sediment delivery would decrease by about 65 percent once project-related log haul traffic ceases—and with continued maintenance of NFS roads. Timber harvest on state and private lands within the cumulative effects analysis area would continue. Sediment delivery would be limited through compliance with the Washington State Forest Practice Rules, as described above. Livestock grazing would continue on NFS lands, with improved grazing practices that are intended to improve riparian conditions, stream habitat, and water quality. Livestock grazing along private lands would also likely continue, with unknown effects on stream habitat. Downstream from the project boundary within the mainstem of Mill Creek, cumulative sediment delivery effects potentially could occur due to the combined sediment delivery to the Middle Fork, South Fork, and the North Fork of Mill Creek. However, a net short- and long-term sediment delivery decrease is predicted for each of these subwatersheds, and therefore would also be predicted to occur within Mill Creek. Since there would be no added negative effect on sediment delivery to Mill Creek from Alternative C to the effects of other past, present or reasonably foreseeable future actions, cumulative effects would not occur.

3.5 Forest Plan Consistency

Prescribed fire and other treatments under the modified proposed action would reduce the risk of high-severity stand-replacing wildfires and attendant increased sediment delivery that would likely result in damage to stream channels, fish habitat, and contribute to water quality degradation. Project scoping identified effects on sediment delivery as a cumulative effects concern affecting water quality and stream channels. The sediment delivery analysis reported within this Hydrology report is a cumulative effects analysis addressing both NFS and other ownerships.

The modified proposed action would also comply with the direction provided by INFISH (USDA 1995) by maintaining stream channel integrity, channel processes, and the sediment regimes under which the riparian and aquatic ecosystems within and downstream from the project area developed.
The project would comply with the Clean Water Act by applying standards and guidelines described in the Forest Service Manual and Handbook, General Water Quality - Best Management Practices and the Inland Native Fish Strategy (INFISH) riparian goals, and would implement the INFISH Riparian Habitat Conservation Area requirements. The project would also address the cumulative effects posed by sediment delivery by conducting the WEPP:Road and WEPP:FuME sediment delivery analyses for all ownership within the Middle and South Fork project area subwatersheds where meaningful watershed analyses could be conducted.

3.6 Unavoidable Adverse Impacts
Sediment delivery increases associated with extensive commercial harvest, shaded fuel break treatments, and road management and use activities are unavoidable. However, because of road sediment delivery improvement projects purposefully incorporated as project activities, sediment delivery decreases from the existing condition and in relation to natural background conditions.

3.7 Irretrievable or Irreversible Commitment of Resources
No irretrievable or irreversible commitments of resources related to sediment delivery were identified in any of the action alternatives.

CHAPTER IV STREAMFLOW
The issue indicators used to evaluate effects of commercial harvest and shaded fuel break treatments upon streamflow regimes are:

- Percent change in peak flow over natural baseline
- Percent change in annual water yield over natural baseline
- Percent change in low flow over natural baseline

4.1 Assessment Methods
Peak flows can be altered by forest harvest activities. Removal of canopy causes less interception of precipitation, more snow accumulation, and more snowmelt available for runoff (Troendle and King 1985). This analysis utilizes the Hydrologic Change methods outlined by Washington States Standard Methodology for Conducting Watershed Analysis (WFPB 2011). By using these procedures, changes in forest cover are used to calculate changes in peak flows during simulated storm events. Potential for project activities to damage channel morphology and aquatic habitat is then inferred based on the percentage increase in predicted peak flow. The scientific literature demonstrates that low flows and total water yield nearly always increase following extensive harvest, however these increases vary in magnitude and generally are of short duration; based on the extent of canopy removal associated with the alternatives, effects on water yield and low flows are inferred.

For the purposes of assessing total and cumulative effects from the project design, the analysis was conducted on the entire Middle Fork Mill Creek, South Fork Mill Creek, and Camp Creek subwatersheds, each as a single hydrologic analysis unit. 48.8 percent of the Middle Fork subwatershed, 37.8 percent of the South Fork subwatersheds, and 12.4 percent of the Camp Creek subwatershed within the project area would receive commercial harvest and shaded fuel break
canopy-removing silvicultural treatments.\textsuperscript{11} Peak flow response was simulated for these subwatersheds in order to better understand the potential effect of project-related commercial harvest and shaded fuel break treatments taken cumulatively with past and foreseeable future harvest on other ownerships outside the project area. Other stream drainages that have headwaters within the project area are substantially less influenced by the proposed treatments and effects are inferred based on findings for the simulated subwatersheds.

Following the WFPB (2011) procedures, an estimate of rain plus snowmelt water available for runoff (WAR) is developed. Estimation of WAR requires addition of the estimated 24-hour snowmelt to the 24-hour precipitation for a given return interval. Snowmelt is determined by simulating a 24-hour storm event occurring over a modeled snowpack, taking into account effects of forest cover on snow accumulation and wind speed.

The three simulated subwatersheds were categorized based on elevation/air temperature relationships into precipitation zones: rain-dominated, rain-on-snow (transient zone), snow-dominated, and highland areas.

Snow accumulates to a greater depth in open forest than it does under canopy cover, and snow melts faster in open forests during rain-on-snow (ROS) conditions due to greater wind speeds over the snowpack. Coefficients used for snow accumulation and melt calculations using the WFPB (2011) procedures vary by precipitation zone and canopy density maturity classes as shown in Table 4. Essentially, these coefficients are ratios of the inches of water available in the snowpack for melt for the various cover conditions examined. Mature stands have an R value of 1; all other cover conditions have R values greater than 1, which translates into more water available for melt and runoff. The snow water equivalent (SWE) values were calculated using the Columbia-Pend Oreille SWE/elevation regional regression equation (WFPB 2011). For the immature and intermediate hydrologic maturity classes, SWE values (which assume hydrologically mature forest) were multiplied by the appropriate ratio in Table 4. Table 4 also shows the forest cover wind coefficients ($F_c$), which are used in the snowmelt simulation to account for the lower wind speeds that occur in denser stands.

\textbf{Table 4. Coefficients used for snow accumulation and melt calculations (WFPB 2011)}

<table>
<thead>
<tr>
<th>Cover class</th>
<th>R (Snow water equivalent ratio)</th>
<th>$F_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rain</td>
<td>ROS</td>
</tr>
<tr>
<td>Mature</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.75</td>
<td>1.5</td>
</tr>
<tr>
<td>Immature</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Non-forest</td>
<td>2.5</td>
<td>2</td>
</tr>
</tbody>
</table>

\textsuperscript{11} Review of existing canopy conditions from orthoimagery for stands that would be precommercially thinned per the action alternatives indicated intermediate hydrologic maturity class for existing conditions; these stands would not move to the immature class with thinning.
The snow water equivalent equation for the Columbia – Pend Oreille region provided by WFPB (2011) was applied to estimate the SWE as a function of elevation:

\[ \text{SWE} = -13.838 + 0.02716E \]

SWE is the snow water equivalent; where SWE is in inches, and E is elevation in feet.

Snowmelt is computed from the following equation (WFPB 2011):

\[ \text{SM} = T (0.133 + 0.086v + 0.0126P) + 0.23; \]

where SM is the 24-hour snowmelt in cm, T is the air temperature in degrees Celsius, v is the adjusted wind speed in m/s, and P is the 24-hour precipitation in cm. The adjusted wind speed is calculated from:

\[ v = u (1 - 0.8F_c); \]

where \( u \) is the average wind speed in m/s, and \( F_c \) is obtained from Table 4. The snowmelt calculated from the WFPB method is added to the 24-hour precipitation to estimate a total WAR for each return interval and cover condition.

In order to establish a relationship for mid-winter and spring conditions between elevation and temperature, equations used by Greenberg (1995) were applied:

- Mid-winter (January 1): \( T_w = 2.9 - (0.006 \times E) + 1.7 \), and
- Spring (May 1): \( T_s = 21.82 - (0.01099 \times E) \);

where \( T \) is in degrees Celsius, and \( E \) is elevation in feet.

Results using the mid-winter equation produced temperature values within the project area below 0° C at all elevations and therefore produced no snowmelt. Land use canopy changes do not increase streamflow in winter months within the project area under these conditions. Also, peak flow events within the project area occur during April and May spring conditions (Bodhaine and Thomas 1960). Therefore the mid-winter modeling scenario was dropped from further consideration, and only spring rain-on-snow conditions were modeled.

The spring equation yielded a temperature of 16.6° C that compared favorably to Colville, WA meteorological data, where May 1 mean daily temperatures were 11.6 C and maximum daily values were 19.5° C, respectively.

24-hr precipitation amounts used in this assessment were developed from NOAA’s Precipitation-Frequency Atlas (NOAA 2011) and are listed in Table 5.

<table>
<thead>
<tr>
<th>Return Interval (years)</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-hour precipitation (in)</td>
<td>1.69</td>
<td>2.03</td>
<td>2.28</td>
<td>2.54</td>
<td>2.79</td>
<td>3.14</td>
</tr>
</tbody>
</table>
With these inputs, and using the procedures of Brunengo et al. (1992), precipitation zones were defined as shown in Table 6. Elevations of mid-winter (January 1) precipitation zones were obtained from the Washington Department of Natural Resources (WDNR) snow depth equivalent feature class containing statewide coverage of precipitation zones: (fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html#Climatology). Although mid-winter conditions are too cold to provide snowmelt, the elevations mapped by WDNR provide the basis for spring precipitation zones which are listed in Table 6. The spring precipitation zones were shifted upward in elevation by 1,200 feet based on nearby snow course and SNOTEL May 1 SWE data (Figure 29).

**Table 6. Mid-winter and spring precipitation zones**

<table>
<thead>
<tr>
<th>Precipitation Zone</th>
<th>Elevation range for mid-winter</th>
<th>Elevation range for spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain-dominated</td>
<td>&lt; 2,000 ft.</td>
<td>&lt; 3,200 ft.</td>
</tr>
<tr>
<td>Rain-on-snow</td>
<td>2,000 ft. – 3,200 ft.</td>
<td>3,200 ft. - 4,400 ft.</td>
</tr>
<tr>
<td>Snow-dominated</td>
<td>3,200 ft. – 4,800 ft.</td>
<td>4,400 ft. - 6,000 ft.</td>
</tr>
<tr>
<td>Highland</td>
<td>&gt; 4,800 ft.</td>
<td>&gt; 6,000 ft.</td>
</tr>
</tbody>
</table>

**Figure 29. Spring precipitation zones**

The simulated subwatersheds were classified into hydrologic maturity classes based on interpretation of 2013 NAIP digital imagery and field observation. Washington State assessment procedures define hydrologic maturity as follows:

Mature: > 70 percent crown closure and < 75 percent hardwoods or shrubs

Intermediate: 10 percent - 70 percent crown closure and < 75 percent hardwoods or shrubs
Immature: < 10 percent crown closure or > 75 percent hardwoods or shrubs

Non-forest: Surface water, rock outcrop, meadow, agricultural, etc.

Once hydrologic maturity classification was complete, GIS analysis was employed to compute subwatershed area by precipitation zone by maturity class for each of the alternatives based on the January 20th, 2016 project footprint. Different hydrologic maturity class scenarios were then examined, including current condition (No Action alternative A), historic fire disturbance, action alternatives B and C, and for conditions associated with HRV (Table 7, Table 8, and Table 9). By applying WAR estimates, peak flows were determined at different recurrence intervals for these scenarios. Local streamflow, precipitation, snow water equivalent, temperature, and wind records were examined, including data sources documented within other nearby hydrologic change assessments, including Big Sheep Creek near Northport (Greenberg 1995) and Huckleberry Creek near Chewelah (WDNR 1995). Detailed worksheets and model outputs are listed in Appendix F.

Table 7. Subwatershed areas by precipitation zone by cover class for spring storm, Middle Fork Mill Creek subwatershed

<table>
<thead>
<tr>
<th>Precipitation Zone</th>
<th>Cover Class</th>
<th>HRV</th>
<th>Existing Condition</th>
<th>Existing with Wildfire</th>
<th>Alternative B</th>
<th>Alternative C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>Mature</td>
<td>773</td>
<td>1,510</td>
<td>906</td>
<td>642</td>
<td>844</td>
</tr>
<tr>
<td>Rain</td>
<td>Intermediate</td>
<td>618</td>
<td>36</td>
<td>22</td>
<td>904</td>
<td>702</td>
</tr>
<tr>
<td>Rain</td>
<td>Immature</td>
<td>155</td>
<td>0</td>
<td>618</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rain</td>
<td>Non-forest</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Mature</td>
<td>2,878</td>
<td>5,271</td>
<td>3,163</td>
<td>2,409</td>
<td>2,908</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Intermediate</td>
<td>2,302</td>
<td>422</td>
<td>253</td>
<td>3,237</td>
<td>2,737</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Immature</td>
<td>576</td>
<td>63</td>
<td>2,340</td>
<td>111</td>
<td>111</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Non-forest</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Snow</td>
<td>Mature</td>
<td>483</td>
<td>764</td>
<td>458</td>
<td>245</td>
<td>341</td>
</tr>
<tr>
<td>Snow</td>
<td>Intermediate</td>
<td>386</td>
<td>123</td>
<td>74</td>
<td>641</td>
<td>545</td>
</tr>
<tr>
<td>Snow</td>
<td>Immature</td>
<td>97</td>
<td>80</td>
<td>434</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Snow</td>
<td>Non-forest</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Mature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Intermediate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Immature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Non-forest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8,319</td>
<td>8,319</td>
<td>8,319</td>
<td>8,319</td>
<td>8,319</td>
</tr>
</tbody>
</table>

12 Subsequent to the 1/20/16 footprint, several relatively minor changes were made to reduce wildlife, soil, riparian and other resource impacts. The primary change affecting the peak flow increase predictions is that harvest area was reduced by 288 acres (2.5 percent) for Alternative B, and by 498 acres (5.0 percent) in Alternative C. These changes cause the acres affected by harvest, and the predicted peak flow responses based on them, to be roughly proportionately high. The effect is minor, and did not warrant remodeling and revised reporting of effects.
Table 8. Subwatershed areas by precipitation zone by cover class for spring storm, South Fork Mill Creek subwatershed

<table>
<thead>
<tr>
<th>Precipitation Zone</th>
<th>Cover Class</th>
<th>HRV</th>
<th>Existing Condition</th>
<th>Existing with Wildfire</th>
<th>Alternative B</th>
<th>Alternative C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>Mature</td>
<td>1,742</td>
<td>2,982</td>
<td>1,789</td>
<td>1,920</td>
<td>2,121</td>
</tr>
<tr>
<td>Rain</td>
<td>Intermediate</td>
<td>1,394</td>
<td>471</td>
<td>282</td>
<td>1,512</td>
<td>1,322</td>
</tr>
<tr>
<td>Rain</td>
<td>Immature</td>
<td>348</td>
<td>32</td>
<td>1,413</td>
<td>53</td>
<td>42</td>
</tr>
<tr>
<td>Rain</td>
<td>Non-forest</td>
<td>356</td>
<td>356</td>
<td>356</td>
<td>356</td>
<td>356</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Mature</td>
<td>6,341</td>
<td>11,237</td>
<td>6,742</td>
<td>5,227</td>
<td>6,381</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Intermediate</td>
<td>5,073</td>
<td>1,352</td>
<td>811</td>
<td>7,267</td>
<td>6,154</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Immature</td>
<td>1,268</td>
<td>93</td>
<td>5,128</td>
<td>188</td>
<td>146</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Non-forest</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>Snow</td>
<td>Mature</td>
<td>574</td>
<td>811</td>
<td>486</td>
<td>694</td>
<td>694</td>
</tr>
<tr>
<td>Snow</td>
<td>Intermediate</td>
<td>459</td>
<td>337</td>
<td>202</td>
<td>444</td>
<td>444</td>
</tr>
<tr>
<td>Snow</td>
<td>Immature</td>
<td>115</td>
<td>0</td>
<td>459</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Snow</td>
<td>Non-forest</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Highland</td>
<td>Mature</td>
<td>1,166</td>
<td>1,358</td>
<td>815</td>
<td>989</td>
<td>1,200</td>
</tr>
<tr>
<td>Highland</td>
<td>Intermediate</td>
<td>932</td>
<td>695</td>
<td>417</td>
<td>1,046</td>
<td>844</td>
</tr>
<tr>
<td>Highland</td>
<td>Immature</td>
<td>233</td>
<td>279</td>
<td>1,100</td>
<td>296</td>
<td>287</td>
</tr>
<tr>
<td>Highland</td>
<td>Non-forest</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17,749</td>
<td>17,749</td>
<td>17,749</td>
<td>17,749</td>
<td>17,749</td>
</tr>
</tbody>
</table>

Table 9. Subwatershed areas by precipitation zone by cover class for sprint storm, Camp Creek subwatershed

<table>
<thead>
<tr>
<th>Precipitation Zone</th>
<th>Cover Class</th>
<th>HRV</th>
<th>Existing Condition</th>
<th>Existing with Wildfire</th>
<th>Alternative B</th>
<th>Alternative C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>Mature</td>
<td>81</td>
<td>114</td>
<td>69</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>Rain</td>
<td>Intermediate</td>
<td>65</td>
<td>47</td>
<td>28</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Rain</td>
<td>Immature</td>
<td>16</td>
<td>0</td>
<td>65</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rain</td>
<td>Non-forest</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Mature</td>
<td>1,166</td>
<td>1,358</td>
<td>815</td>
<td>989</td>
<td>1,200</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Intermediate</td>
<td>932</td>
<td>695</td>
<td>417</td>
<td>1,046</td>
<td>844</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Immature</td>
<td>233</td>
<td>279</td>
<td>1,100</td>
<td>296</td>
<td>287</td>
</tr>
<tr>
<td>R-O-S</td>
<td>Non-forest</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Snow</td>
<td>Mature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Snow</td>
<td>Intermediate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Snow</td>
<td>Immature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Snow</td>
<td>Non-forest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Mature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Intermediate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Immature</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Highland</td>
<td>Non-forest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,599</td>
<td>2,599</td>
<td>2,599</td>
<td>2,599</td>
<td>2,599</td>
</tr>
</tbody>
</table>

The percent increase in peak flow discharge at various storm frequencies (i.e. the 2-year storm, the 50-year storm, etc.) indicates potential for damage to fish habitat. Larger storm and flood magnitudes (25-year through 100-year) are of greatest concern relative to flood potential, while impacts to fish habitat are more focused on increasing the occurrence of the channel-forming discharge increases thought to be approximately the 5-year discharge in steep mountain streams; inferring that sufficient bed and bank scour occurs for this to be the important channel forming event, while the 2-year discharge in lower gradient unconstrained channels (WFPB 2011).
It is assumed within the WFPB (2011) procedures that there are no adverse effects for peak flow increases up to 10 percent. Peak flow increases greater than 10 percent offer the possibility for adverse effects if there is potential for downstream flood damage, using the 25-year flow as the indicator, or scour damage to fish spawning areas, using the 2-year event as the indicator.

4.2 Scope of Analysis

The Middle and South Fork Mill Creek A to Z Project area includes all of the Middle Fork Mill Creek and South Fork Mill Creek subwatersheds, and includes headwater portions of the Camp Creek, Squaw Creek, Amazon Creek and Narcisse Creek subwatersheds. Potential effects of project activities were examined in each subwatershed. Potential effects on peak flows were simulated for the Middle Fork Mill Creek, South Fork Mill Creek, and Camp Creek subwatersheds. Area affected by proposed project treatments and on other ownership within project boundaries within the Squaw, Amazon and Narcisse Creek subwatersheds is minor; simulation of peak flow effects in these subwatersheds was not necessary for formation of professional opinion regarding direct, indirect or cumulative effects within them.

Analysis at this scale was selected so as to be consistent with Ecosystem Analysis at the Watershed Scale - Federal Guide to Watershed Analysis (Federal Guide) (REO 1995) and with INFISH (1995), which states that watershed analysis will follow the Federal Guide procedures. Appropriate scale of analysis is discussed at some length within the Guide. The Federal Guide states that “Watershed is a useful term to associate with all areas resulting from the first subdivision of a subbasin. The watershed, then, is the fifth largest level in the hierarchy and is often referred to as a “fifth-field watershed.” The example given for “watershed” at page 6 of the Federal Guide is Fall Creek, a subdivision of the Middle Fork of the Willamette River, a fifth-field watershed. The combined area of the Middle Fork and South Fork subwatersheds comprises a 6th-field (12-digit HUC) subwatershed and, individually, they are 7th-field subwatersheds—meaning that they are smaller subdivisions than suggested for analysis by the Federal Guide. Furthermore, the Federal Guide states that “When planning a watershed analysis, teams should consider the size of the watershed relative to data needs, data availability, resolution, and time and resource requirements, as well as the issues to be addressed”, and “Teams generally should avoid analyzing watersheds significantly smaller than 20 square miles or larger than 200 square miles”. The South Fork area is a 27.73 square mile subwatershed. The Middle Fork area is a 13.00 square mile subwatershed.

4.3 Current Conditions

The climate of the project area is affected by both maritime and continental air masses that influence precipitation and temperature patterns. In the summer the maritime influence from the Pacific Ocean is dominant, while in the winter arctic air from Canada is dominant. The closest location to the project area with continuous records of climatic data is Colville, Washington, which lies 8 miles southwest of the project area at an elevation of 1,877 feet. Elevations within the project area vary from 5,773 feet at Old Dominion Mountain to 2,200 feet where South Fork Mill Creek exits the project area. Air temperatures are considerably cooler than in Colville, precipitation is greater, and snowpacks are deeper and more persistent.

Stand density as evaluated by canopy closure, a key factor in assessing streamflow regime, has recovered from the extensive wildfire that occurred within the project area in the 1920s. However, considerable effect on canopy cover from logging persists, particularly on non-NFS lands within the area, where recent logging is commonplace. In general however, current average
canopy density within the project area is higher than long-term averages when compared to canopy closure associated with more naturally-occurring stand development stages as affected by wildfire and in the absence of fire-suppression. Existing canopy within project area subwatersheds is relatively dense on NFS lands: Canopy density on the smaller acreage of state and private lands is mixed (Figure 30).

Figure 30. Middle and South Fork Mill Creek Project hydrological maturity classification, existing condition

The WFPB (2011) procedures suggest comparison to a hypothetical “fully forested” scenario where all stands are considered to be hydrologically mature. However, such a scenario does not realistically represent eastside forest conditions as affected naturally through time and the conditions that have affected stream channels. This “natural” condition is more realistically based on “historic range of variability” (HRV) estimates of stand development stages and canopy closure / hydrologic maturity class conditions.

Using the biophysical environments and range of historic variability from Berube and Kovalchik (1995) which are presented in the Silviculture/Fire specialist report, the project area consists of mostly Cool Mesic Douglas-fir forest type. Using the vegetative historic range of variability for these types of Douglas-fir forests, approximately 10 percent of the project area would be expected to exist naturally as a stand initiation structural development condition. This structural development stage coincides with the WFPB immature cover type classification. Also from these tables, approximately 40 percent of the project area would be expected to occur naturally as stem exclusion/open canopy or as old forest/multi-strata (older forest with canopy openings). Both of these development stages coincide with the WFPB intermediate canopy density class. For modeling purposes, combined immature and intermediate canopy density classes total 50 percent for the HRV condition.
Compared to the HRV condition, canopy for the existing condition is much more mature for the Middle and South Fork subwatersheds, and roughly comparable for the Camp Creek subwatershed (Figure 31, Figure 32, and Figure 33).

Figure 31. Existing hydrologic maturity compared to hydrologic maturity based on HRV conditions, Middle Fork Mill Creek subwatershed

Figure 32. Existing hydrologic maturity compared to hydrologic maturity based on HRV conditions, South Fork Mill Creek subwatershed
Without wildfire, stand development would continue within the project area without major disturbance events, and long-term, stands would develop towards hydrologically mature stands. Short-term, there would be no immediate changes in the distribution of hydrologic maturity on National Forest System lands. Peak flows, total water yield, and seasonal low flows would reflect the existing condition. Based on hydrologic maturity of the canopy, magnitude of peak flows for the Middle Fork, South Fork and Camp Creek subwatersheds are less than what would be expected to be produced by the HRV condition (Table 10), as are total water yield, and seasonal low flows. Fuel build-up and stand conditions would continue to develop that increase the likelihood of large, stand-replacing wildfire.

**Table 10. Percent decrease in peak flow predicted for the existing condition relative to the HRV condition**

<table>
<thead>
<tr>
<th>Subwatershed</th>
<th>2-year event</th>
<th>25-year event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Fork</td>
<td>11.3</td>
<td>7.8</td>
</tr>
<tr>
<td>South Fork</td>
<td>10.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Camp Creek</td>
<td>2.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

The largest floods on record—as recorded by stream gauges in the vicinity of the project area—occur in April and May (Bodhaine and Thomas 1960), consistent with peak flows recorded for nearby Sheep Creek and other streams in the vicinity (Greenberg 1995).

Concerning the water yield and low flow issues, the Washington Department of Ecology (2012) reports for the Colville River Basin (including its tributary, Mill Creek) that groundwater and surface water are least available when water demands are highest during summer months; no water is available for further consumptive appropriation except for in-house single domestic supply or stock watering in some cases.
Figure 34 shows a hydrograph of mean daily flows in cubic feet per second per square mile (cfs/m) from the discontinued Mill Creek gaging station (USGS 12408500) based on water years 1940 through 1986 that was located downstream of the planning area. Mean daily flows are highest during the snowmelt period of April and May, with lowest flows in August and September.

![Mill Creek USGS #12408500: Mean Daily Flow](image)

**Figure 34.** Mill Creek annual hydrograph showing typical streamflow throughout the year

### 4.4 Management Prescriptions

Management prescriptions for the project area were considered pursuant to the planning guidance discussed earlier at Regulatory Framework. More specifically, if through analysis, increases in peak flows were found to exceed acceptable limits, damage to stream channels and fish habitat could occur. However, as discussed above, canopy density post-Project for alternatives B and C would be little-different than that for the HRV condition, and peak flows post-Project are predicted to be less than associated with HRV. Similarly, water yield and low flows would be little-different than what would be expected for the HRV condition. No specific management prescriptions were found to be necessary.

### 4.5 Environmental Consequences

This section provides a detailed analysis of potential effects of the No Action and action alternatives related to streamflow. This analysis addresses the effects of the modified proposed action and alternatives summarized in Chapter II of the final EA and described in detail in resource specialist reports. The analysis considers implementation of design elements described in Chapter II intended to avoid or minimize adverse impacts streamflow regimes.

#### 4.5.1 Literature Review

Forest harvest activities have potential to produce hydrologic changes, and effects have been well documented in the Pacific Northwest (Harr and McCorison 1979; Jones and Grant 1996; Storck et al. 1998; Thomas and Megahan 1998; VanShaar et al. 2002; Moore and Wondzell 2005).
Although these potential hydrologic changes also include low flows and total water yield, changes to peak flow are of primary interest with respect to potential damage to channel morphology and aquatic habitat (Grant et al. 2008). Peak flows can be altered by forest harvest activities after removal of canopy through less interception, which results in more snow accumulation and snowmelt available for runoff (Troendle and King 1985).

In an extensive recent review of the effects of harvesting on forest hydrology, Buttle (2011) reviews literature reporting that massive deforestation in Central American rainforests may decrease rainfall due to reduced transpiration, surface roughness and reduced albedo. However, Buttle (2011) also cites contradictory, peer-reviewed, published accounts indicating that current levels of deforestation in Amazonia and other tropical regions may enhance convection and promote an increase in precipitation.

Contrasting sharply with conditions reported for tropical rainforests, the Middle and South Fork Mill Creek A to Z Project area lies within the Northern Rockies Ecoregion (EPA 2010), characterized by winters dominated by cold temperatures and snowfall, and warm dry summers. Concerning effects within North America, Buttle (2011) reports that forest harvesting generally increases net precipitation reaching the forest floor—as a result of reduced interception losses—by 10 to 50 percent. The two western North America exceptions to this general rule reported within the literature are for the Bull Run municipal watershed in the Oregon Cascades near Portland and within an Oregon Coast Range forest (Harr 1982) due to forest canopy interception of fog. Reduced water yield was reported by Harr (1982) for the Bull Run experiment. However, the preponderance of the literature reports increased water yield and streamflow following harvest: Bosch and Hewlett (1982) report increased streamflow in 93 of 94 North American research studies that they located and reviewed, due to partial or complete (depending on harvesting intensity) elimination of canopy interception and subsequent evaporation combined with elimination of evapotranspiration from the harvested trees. In addition, in areas subject to winter snow-dominated regions—including the MSF project area—removal of canopy causes less interception of snowfall, more snow accumulation on the forest floor, and more snowmelt available for runoff (Troendle and King 1985; WFPB 2011).

In summary, the literature applicable to the project area indicates that gross above-canopy precipitation would be unaffected, while net precipitation received at the forest floor, soil moisture, and streamflow would increase following tree removal under the action alternatives.

Nearly all studies of forest harvesting effects in North America have demonstrated that total soil moisture content and volume of streamflow runoff increases for several years following forest harvesting (Bosch and Hewlett 1982). Where increases have been demonstrated, increases are greatest during the first year following logging, and effects decrease in the following years as vegetation regenerates and matures (Megahan 1976). Increases persist longest in drier areas where vegetative regrowth is slow. In most cases, both spring and summer flows increase, while occasionally summer flows remain unaffected. (Bosch and Hewlett 1982; Troendle 1983; Troendle 1988; Hubbart et al. 2007). Increases in streamflow are generally proportional to the amount of cover removed, with clearcutting producing larger increases than partial cutting (Rothacher 1971; Keppeler 1998). Results from several studies suggest that approximately 20 percent of forest basal area must be removed before a statistically significant change in annual runoff can be detected (Bosch and Hewlett 1982; MacDonald and Stednick 2003).

Summer low flows also typically increase following forest harvesting because forest soils remain moister during the summer as reduced water use by trees (evapotranspiration) allows soils to
remain wetter into the summer dry season, and more water is released as surface flow to streams (Troendle 1988; Harr and McCorison 1979; Harr 1983; Keppeler 1998). The absolute magnitude of the volume increase in low flows is generally small (because the low flows themselves are so small), but percentage increases due to clearcutting of 50 percent to 100 percent above pre-harvest flows have been found. Contradictory results are also reported: In northern Idaho, Hubbart et al. (2007) found negligible summer low flow increases following harvest.

Peak flows also generally increase following harvest. Increases for both water yield and peak flows have been directly observed only in small basins (generally first or second order); as drainage area increases to third or fourth order and larger streams, flow increases become very difficult to detect (Harr 1989; King 1979).

Forest harvest has a progressively smaller effect on peak flows as flood recurrence interval (i.e. bigger floods) increases (Grant et al. 2008). In western Oregon, Thomas and Megahan (1998) found a 23 percent increase in 1 to 2-year return interval flows resulting from 100 percent clearcut, but no detectable increases in flows greater than the 2-year return interval flow. Since it is normally the higher flows (i.e., 2-year return interval or greater) that are of concern in terms of channel morphology and stream habitat, the potential effects of harvest on stream characteristics may be minimal. This likelihood is corroborated by results from Madsen (1995) in northwestern Montana and Berkompas (2002) in northern Idaho.

Roads also can potentially change watershed hydrology and peak flows. It has been suggested that roads may increase peak streamflow by capturing subsurface water in road cuts and by generating excess surface flows from compacted road surfaces (Coe 2004). While this potential exists, the effect of roads on the magnitude and timing of peak flows is poorly understood (Wemple et al. 1996), and research results are mixed.

It also has been suggested that increases in peak flows from roads may be due to increases in “drainage density” stemming from connectivity between the road system and the stream network at channel crossings and through gullies below relief drains (Montgomery 1994; Wemple et al. 1996; and Jones 2000). However, road mileage that drains to streams is not the same as an increase in the length of streams in the watershed (Jones 2000). If drainage density did actually increase because of road connectivity, relationships developed for natural drainages linking flood peaks and low flows to drainage density should be suitable for predicting the flow changes that occur from increased “drainage density” from road construction. However, studies of road construction effects within experimental watersheds show no such effects (Harr et al. 1975; Rothacher 1973; King and Tennyson 1984).

Arguments are made that runoff from intercepted subsurface flow occurs rapidly as concentrated overland flow, and therefore tends to increase peak flows (Jones and Grant 1996). This effect may or may not occur. Potential effects of roads on peak flows depend on the specific characteristics of the road and the watershed in question. For example, according to Gucinski et al. (2001):

The effects of roads on peak streamflow depend strongly on the size of the watershed; for example, capture and re-routing of water can dewater one stream while causing major channel adjustments in the stream receiving the additional water. In large watersheds, roads constitute a small proportion of the land surface and have relatively insignificant effects on peak flow.
Field studies of the effects of road construction on peak flows in experimental watersheds at the Horse Creek Experimental Watershed in North-Central Idaho have demonstrated mixed results following road construction; some watersheds show peak flows increasing, some decreasing, and others show no statistical change (King and Tennyson 1984).

In western Oregon, Jones and Grant (1996) concluded that 6 percent of the area occupied by roads in a small (250 acre) watershed caused a 20 percent (statistically non-significant) increase in mean annual peak flows. However, using a different statistical methodology with the same data set as Jones and Grant (1996), Thomas and Megahan (1998) found statistically significant increases in peak flows in the small watershed that was roaded and patch-cut, but only in the first 10-year period following harvest. This implied that the effect was due to harvest (with little effect from roads), as road effects should have persisted beyond ten years.

Potential effects of past and ongoing harvest and roads on peak flows and stream channels also need to be viewed in comparison to effects that have occurred due to wildfires. Because wildfires often burn over extensive areas (even entire third order or larger watersheds), and because they often burn with severe intensity, Harr (1989) concluded that wildfire-induced peak flow increases are likely greater than those caused by forest harvesting and prescribed burning practices—which usually are limited to much smaller areas at any given time. Peak flow increases following wildfire often exceed 40 percent to 60 percent during the first year or two following fire, when effects are most pronounced (Anderson 1976; Helvey 1973; Beschta 1990), and can reach several hundred percent (Troendle and Bevenger 1993).

4.5.2 Direct and Indirect Effects

4.5.2.1 Analysis Indicators

The analysis indicators used to evaluate effects on streamflow regime are:

- Percent change in peak flow over natural baseline

  This metric represents the potential for project activities—essentially canopy removal associated with commercial harvest and shaded fuel break treatments—to exceed thresholds that potentially could destabilize stream channels and channel substrate. The specific threshold applied for project subwatersheds is a greater than 10 percent increase in the 2-year or 25-year peak flow above the peak flow associated with HRV conditions, the conditions most representative of those under which the riparian and aquatic ecosystems developed within the project area. Three subwatersheds were analyzed: Middle Fork Mill Creek; South Fork Mill Creek; Camp Creek.

- Percent change in annual water yield and percent change in low flow over natural baseline

  As indicated by the literature reviewed above, forest harvest has nearly always been shown to increase water yield and low flows. Given that the Washington Department of Ecology (2012) reports for the Colville River Basin (including its tributary, Mill Creek) that groundwater and surface water are least available when water demands are highest during summer months, and that no water is available for further consumptive appropriation except for in-house single domestic supply or stock watering in some cases, increases in water yield and low flows are considered beneficial for the project area.
Short-term effects to streamflow were assessed for the period of time within 5 years of treatment. These effects diminish over time. Long-term effects were evaluated for the period of time beyond 5 years post-treatment. Based on response following past harvest activities, canopy cover is expected to recover to the hydrologically mature condition on treated areas within 30 years.

4.5.2.2 Alternative A – No Action

4.5.2.2.1 Methods and Assumptions

Methods for predicting effects of canopy removal on peak flows were described earlier at the Assessment Methods section. For hydrologically mature stands, it was assumed that uneven-aged silvicultural treatments would decrease canopy density short-term to the intermediate maturity class. For hydrologically intermediate stands, it was assumed that maturity class would not change with uneven-aged silvicultural treatments. It was also assumed that all even-aged silvicultural treatments would result in hydrologically immature stands, short-term. Long-term, it was assumed that all stands would develop towards hydrologically mature stands. Long-term scenarios were not simulated.

The modeling scenario for Alternative A with wildfire assumes that 40 percent of mature and intermediate hydrologic maturity areas within the project area are affected by stand-replacement fire where canopy density is decreased to less than 10 percent; the immature forest condition.\(^\text{13}\)

4.5.2.2.2 Direct and Indirect Effects

Under Alternative A with wildfire, spring rain-on-snow peak flows are predicted to be substantially higher than for the existing condition. Compared to the more-meaningful HRV condition, peak flows with wildfire for the Middle and South Fork subwatersheds only moderately increase, and would not be expected to adversely affect stream channels and fish habitat or substantially increase the probability of flood damage. However, an 11.2 percent increase in the 2-year (Q2) spring rain-on-snow peak flow above that predicted for the HRV condition is predicted for the Camp Creek subwatershed, which when combined with increased erosion likely to occur following severe wildfire, likely would adversely affect stream channels and fish habitat. The increases in the 25-year (Q25) flood, more meaningful for indexing the probability of flood damage, is predicted to increase by 8 percent for Camp Creek. By itself, this increase may not materially increase the probability of flood damage, but again, when combined with erosion and damage to streambanks likely to occur following severe wildfire, probability of flood damage likely would materially increase (Figure 35, Figure 36, Figure 37 and Figure 38).

Total water yield and seasonal low flows would be expected to measurably increase from current conditions for several years in all three subwatersheds until upland and riparian vegetation matures and exerts pre-fire rates of evapotranspirative demand on soil moisture.

\(^{13}\) These immaturity classes were distributed proportionate to existing cover class percentages for forested portions of the subwatershed and by precipitation zone, but they are not geographically explicit, so no figure is provided to show maturity classes for this alternative.
Figure 35. Middle Fork Mill Creek percent increase in the 2-year (Q2) and 25-year (Q25) peak flows, Alternative A with wildfire

Figure 36. South Fork Mill Creek percent increase in the 2-year (Q2) and 25-year (Q25) peak flows, Alternative A with wildfire
Figure 37. Camp Creek percent increase in the 2-year (Q2) and 25-year (Q25) peak flows, Alternative A with wildfire

Figure 38. Damage to streambanks and channel structure, perennial stream, following the Tepee Springs Fire, Payette National Forest, 2015
4.5.2.3 Alternatives B and C – Action Alternatives

Project effects on streamflow mostly occur through canopy removal associated with commercial timber harvest, shaded fuel breaks, and precommercial thinning, and would differ between Alternative B and Alternative C. Under Alternative B, a total of 11,021 acres of commercial harvest would occur. Under Alternative C, a total of 8,896 acres of commercial harvest would occur. Shaded fuel breaks would be created on approximately 462 acres along major travel routes under both action alternatives. Precommercial thinning would occur on 836 acres under both action alternatives. These are addressed in the section Commercial Harvest Effects. Additional effects on streamflow that could occur through actions common to both action alternatives not associated with commercial harvest are addressed in the Effects Common to Both Action Alternatives section.

4.5.2.3.1 Commercial Harvest Effects

Methods and Assumptions

Following the procedures described above at Assessment Method, effects of canopy removal associated with commercial harvest and shaded fuel breaks on peak flows were simulated for the Middle Fork Mill Creek, South Fork Mill Creek, and Camp Creek subwatersheds. Based on the peer-reviewed scientific literature reviewed at Literature Review, it was assumed that water yield and low flows would increase with canopy removal. Effects upon streamflow metrics associated with forest roads were assumed to not measurably occur, again based on the peer-reviewed scientific literature reviewed at Environmental Consequences. It was also assumed that effects of post-harvest fuel treatment would not materially affect hydrologic maturity of harvested stands beyond that produced by the initial harvest. It was assumed that tree planting could potentially accelerate recovery of hydrologic maturity long-term.

Based on consultation with the silviculture specialists, anticipated prescription applications resulted in the following adjustment to hydrologic maturity classes:

- Variable Density Thinning/Variable Retention Harvest (VDT/VRH), Precommercial thinning (PCT), and Shaded Fuel Breaks: Canopy removal would result in an Intermediate (10 to 70 percent crown closure) maturity class.

- Seed Tree Harvest (STH): Canopy removal would result in an Immature (less than 10 percent crown closure) maturity class.

It should also be noted that, for purposes of evaluating hydrologic maturity, polygons identified as Non-forest remained unchanged as Non-forest, and Retention prescriptions resulted in application of the existing (unchanged) hydrologic maturity class for project alternatives.

Direct and Indirect Effects

Alternative B – Modified Proposed Action

Within the Middle Fork, South Fork and Camp Creek subwatersheds, substantial acreage of forest currently classified as mature (> 70 percent canopy closure) would transition to intermediate density (10 to 70 percent closure) because of commercial harvest, shaded fuel breaks and precommercial thinning. Limited acreage would be reclassified to immature (< 10 percent closure), and stands currently classed intermediate would remain intermediate (Figure 39, Figure
Long-term, it was assumed that all stands would develop towards hydrologically mature stands over time. Long-term scenarios were not evaluated.

Figure 39. Middle and South Fork Mill Creek Project hydrologic maturity classification, Alternative B

Figure 40. Acres by hydrologic maturity class; existing, HRV, and Alternative B conditions, Middle Fork
Based on these changes in stand canopy cover density, magnitude of spring rain-on-snow peak flows are predicted to increase relative to the existing condition. However, relative to the HRV condition, predicted peak flow changes would increase by 0.9 percent for the Middle Fork (Figure 43), would decrease by 0.1 percent for the South Fork (Figure 44), and increase by 2.0 percent for Camp Creek (Figure 45). Damage to channels and fish habitat within and downstream from the project area would not be expected to occur.
Given the expected changes in hydrologic maturity classes, total water yield and seasonal low flows would be expected to measurably increase above existing conditions within the Middle and South Forks of Mill Creek, but not within Camp Creek.

Effects on peak flows, water yield and low flows within the Squaw, Amazon and Narcisse Creek subwatersheds would be expected to be much smaller because substantially smaller percentages of these subwatersheds would be treated.

**Figure 43.** Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the Middle Fork Mill Creek subwatershed, Alternative B

**Figure 44.** Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the South Fork Mill Creek subwatershed, Alternative B
**Figure 45.** Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the Camp Creek subwatershed, Alternative B

**Alternative C – Commercial Harvest without New Road Construction**

Under Alternative C, fewer acres currently classified as mature (> 70 percent canopy closure) would transition to intermediate density (10 to 70 percent closure) because of commercial harvest, shaded fuel break treatments, and precommercial thinning than occurs for Alternative B. Relatively few acres would transition to immature (< 10 percent closure), and stands currently classed intermediate would remain intermediate (Figure 46, 47, 48, and 49). Long-term, it was assumed that all stands would develop towards hydrologically mature stands over time. Long-term scenarios were not evaluated.
Figure 46. Middle and South Fork Mill Creek Project hydrologic maturity classification, Alternative C

Figure 47. Acres by hydrologic maturity class; existing, HRV, and Alternative C conditions, Middle Fork
Based on these changes in stand canopy cover density, magnitude of spring rain-on-snow peak flows are predicted to increase relative to the existing condition. However, canopy cover density under Alternative C is actually greater than for the HRV condition, and peak flows predicted for Alternative C are less than those predicted for HRV. (Figure 50, Figure 51, and Figure 52). Damage to channels and fish habitat within and downstream from the project area would not be expected to occur.
Figure 50. Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the Middle Fork Mill Creek subwatershed, Alternative C

Figure 51. Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the South Fork Mill Creek subwatershed, Alternative C
Given the predicted changes in canopy classes, total water yield and seasonal low flows would be expected to measurably increase above existing conditions within the Middle and South forks of Mill Creek, but not within Camp Creek.

Effects on peak flows, water yield and low flows within the Squaw, Amazon and Narcisse Creek subwatersheds would be expected to be much smaller because substantially smaller percentages of these subwatersheds would be treated.

### 4.5.2.3.2 Effects Common to Both Action Alternatives

#### Methods and Assumptions

As discussed earlier, changes in streamflow regimes are associated with canopy removal. Each of the following activities, with exception of shaded fuel breaks which are evaluated together with commercial harvest addressed at Commercial Harvest Effects, would affect few to no acres of forest canopy and therefore have little to no effect on hydrologic maturity in the project area. Therefore, effects on streamflow regime (peak flow, water yield and low flow) were evaluated qualitatively for activities common to both action alternatives.

#### Direct and Indirect Effects

##### Road Reconstruction and Maintenance

Road maintenance is planned on as about 18 miles of county and 65 miles of NFS roads. Except for the reconstruction of NFS roads 9411175 and 9411130, road maintenance would be conducted on existing road prisms which already have canopy removed. It is assumed that maintenance would not change hydrologic maturity.

A section of NFS road 9411175 would be realigned to eliminate the redundant segment that is adjacent to and parallels Hanson Creek and currently delivers large quantities of sediment to it. About 1.45 miles of the Hanson Creek road would be decommissioned and replaced with 1.41

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**Figure 52. Percent increase in the 2-year (Q2) and 25-year (Q25) peak flows relative to the HRV condition for the Camp Creek subwatershed, Alternative C**
miles of NFS road construction. 1.23 miles of the new route would be located on existing unauthorized road grade, and 0.18 miles require construction. Loss of forest canopy along these roads would be limited to less than one acre, occurring primarily where one corner requires increasing turn radius to 80 feet. Change in hydrologic maturity with the construction would disturb approximately 0.9 acres, assuming a 40-foot width of disturbance.

Reconstruction of road 9411130 would disturb less than one acre.

**Development of borrow pits**

As many as 15 borrow pits may be developed. Under Alternative B, five pits would expand existing borrow pits and ten new borrow pits would be developed. Under Alternative C, five existing borrow pits would be expanded and five new pits would be developed. Development of borrow pits would cause loss of forest canopy in the affected areas. Less than one acre would likely be disturbed per borrow pit planned per action alternatives B and C. Reclamation would occur either upon project completion or after a particular rock source’s resources are exhausted. Reclamation would include replacing overburden, recontouring disturbed areas, and planting trees and grass seed. The cumulative effect of borrow pit development is not expected to affect streamflow regimes measurably (i.e., by less than 0.1 percent).

**NFS road decommissioning**

As many as 7.7 miles of system roads affecting approximately 20 acres may be decommissioned under alternatives B and C. It is assumed that no loss of forest canopy would occur through decommissioning. Long-term, affected road surfaces would be expected to revegetate and forest canopy would be expected to move towards hydrologically mature conditions. The cumulative effect of NFS road decommissioning is not expected to affect streamflow regimes measurably.

**Shaded fuel breaks**

Shaded fuel breaks would be developed on as many as 462 acres under alternatives B and C. Because effects on streamflow regimes from shaded fuel breaks are no different than produced by commercial harvest, results are discussed at Commercial Harvest Effects.

**Precommercial thinning**

Precommercial thinning activities are planned on as many as 836 acres. Because effects on streamflow regimes from precommercial thinnings are no different than produced by commercial harvest; results are discussed at Commercial Harvest Effects.

**Redefinition of pileated woodpecker core area**

Redefinition of pileated woodpecker core area may affect as many as 190 acres. Redefinition of pileated woodpecker core area itself would not remove forest canopy and, therefore, there would be no change in hydrologic maturity. However, commercial harvest would occur within a portion of the area that is currently designated as core area but would no longer be core area under this proposal. This activity is not predicted to affect streamflow regimes.

**Fish passage structure replacement and removal**

As many as 17 fish passage structures may be replaced or removed. This activity is expected to remove less than 1 acre of forest canopy in aggregate, and would have limited effect on hydrologic maturity and no measurable effect on streamflow regimes.
Rehabilitation of areas impacted by user-created trails
As many as 3 acres may be affected by rehabilitation of user-impacted trails. Rehabilitation of these areas would include tree planting on a portion of the area, and hydrologic maturity would be expected to increase long-term. This activity is not predicted to have a measurable effect on streamflow regimes.

Designation of NFS roads open to all vehicles
NFS roads 7018000 and 9411130 would be re-designated. Designation of NFS roads open to all vehicles would not result in loss of forest canopy. This activity would not affect streamflow regimes.

Cumulatively, road reconstruction and maintenance, development of borrow pits, NFS road decommissioning, relocation of pileated woodpecker core areas, fish passage structure replacement and removal, rehabilitation of areas impacted by user-created trails, and designation of NFS roads open to all vehicles would not be expected to measurably affect streamflow regimes short- or long-term. Effects of shaded fuel breaks are considered together with effects of commercial harvest effects within Commercial Harvest Effects.

4.5.3 Cumulative Effects
Cumulative effects related to streamflow are the incremental impacts of an alternative when added to the effects of other past, present, and reasonably foreseeable future actions. See Appendix A of the final EA for a summary of all past, present, and reasonably foreseeable future actions for the project area.

Geographic Scope - The cumulative effects analysis area includes the Middle and South forks of Mill Creek, the North Fork of Mill Creek, Grevit Creek, and Mill Creek immediately downstream of the confluence of the South and North Forks of Mill Creek. The headwaters of the Camp Creek subwatershed that lies within the project area comprises a small part of Little Pend Oreille River basin; therefore, it is not included in the cumulative effects analysis area. Although parts of the Clugston Creek, Onion Creek, Squaw Creek, Amazon Creek, and Narcisse Creek subwatersheds are within the project area boundaries of the North Fork Mill Creek A to Z Project and Middle and South Fork Mill Creek A to Z Project, only small areas of their watersheds lie within the project boundaries and only small parts of these subwatersheds are treated under the action alternatives; they are not included in the cumulative effects analysis area.

Temporal Scope - The timeframe for cumulative effects analysis is thirty years into the future, approximately the timeframe anticipated for re-entry into the project area to address changes in stand structure resulting from proposed treatments and stand development. Based on response following past harvest activities observed via aerial imagery and on-site within the project area, canopy cover would recover to the hydrologically mature condition on treated areas within 30 years. As canopies develop in untreated areas in both subwatersheds without disturbance, hydrologic maturity would increase. Overall, long-term, there would be decreases in the frequency of peak flows and increases in total water yield and seasonal low flow. Cumulative effects on water quality in the future would mostly occur through timber harvest

Past Actions - Nearly the entire cumulative effects analysis area was regenerated by stand-replacing fires in the 1920s. Large areas of hydrologically immature conditions likely existed immediately after these fires, but canopy cover has recovered over time. Past activities occurring in the cumulative effects analysis area that have had additional effects on streamflow regime
include wildfire suppression, timber harvest, road constructions, and conversion of forest lands to pasture and other non-forest land uses (e.g., rural residential development and transmission line corridor construction). The effects of wildfire and past activities in the cumulative effects analysis area subwatersheds are reflected in the existing conditions for their streamflow regimes.

Present and Reasonably Foreseeable Actions - Wildfire suppression, timber harvest, road construction, rural residential use, transmission line corridor maintenance, and livestock grazing are ongoing and are anticipated to be the reasonably foreseeable future actions in the cumulative effects analysis area. Actions in the project area are documented in Appendix A of the final EA. Actions outside the project area are described below. Cumulative effects on streamflow regimes during this timeframe would mostly occur through vegetation treatments. While wildfire suppression would continue to occur, it is not possible to predict when and where these actions may overlap with the effects of the proposed project.

Within the project area, a review of Washington Forest Practice applications (WaDNR 2016) on state and private lands in the project area indicates ongoing and future plans for 274 acres of uneven-aged harvest, 213 acres of even-aged harvest, and less than 0.1 miles of new road construction. Livestock grazing would continue to occur on two NFS grazing allotments, as well as on non-NFS lands. Dispersed recreation would continue, with limited impacts to streamflow. The footprint of rural residential development is not expected to increase in the project area. There are no other known planned major developments or land use changes that would alter disturbance patterns in the project area.

Outside the project area, the Colville National Forest is implementing the North Fork Mill Creek A to Z Project which involves commercial harvest, fuel hazard reduction, precommercial thinning, road reconstruction and maintenance, and habitat restoration at levels comparable to that under the modified proposed action, on a per-acre basis. A review of Washington Forest Practice Applications indicates that timber harvest and road construction on state and private lands are also anticipated to occur at levels comparable to those in the Middle and South Fork Mill Creek A to Z Project area. Livestock grazing on NFS lands would continue on one grazing allotment, as well as on non-NFS lands within the North Fork Mill Creek subwatershed. The footprint of rural residential development and transmission line corridors is not expected to increase. There are no other known planned major developments or land use changes that would alter disturbance patterns in the cumulative effects analysis area.

The effects of other commercial harvest and precommercial thinning on NFS and non-NFS lands would be comparable to those effects assumed for the modified proposed action and described above within this section. Even-aged regeneration harvests would create Immature hydrologic maturity classes. Thinnings and uneven-aged management would create Intermediate hydrologic maturity classes. The effects of other activities such as fuel hazard reduction, road reconstruction and maintenance, and habitat restoration would have incidental to no reduction in forest canopy and, therefore, would have little to no effect on hydrologic maturity. Estimates of associated changes in streamflow are provided below.

4.5.3.1 Alternative A – No Action

Under the No Action alternative, stand development would continue on NFS lands in the Middle Fork Mill Creek and South Fork Mill Creek subwatersheds within the project area without major disturbance events. However, harvest activity on state and private lands in the North Fork Mill Creek subwatershed would be expected to increase 2-year peak flows by less than 1 percent in
each subwatershed. Outside the project area, assessment of harvest that may occur on NFS, state, and private lands within the North Fork Mill Creek subwatersheds indicates that increases in 2-year peak flows would be about 7.5 percent. Because cumulative effects downstream within the mainstem Mill Creek are computed as area-weighted averages of the effects within the upstream subwatersheds, effects within Mill Creek would be less than 10 percent in the short-term; increases would remain well below those that could be expected to affect stream channels, fish habitat, or cause flood damage. Increases in 25-year peak flows would be lower. Long-term, based on the observed response to past treatments in the project area, reductions in hydrologic maturity in the North Fork Mill Creek subwatershed would be relatively short-term as forest canopy cover increases and reverts toward existing conditions. As canopies develop in untreated areas, hydrologic maturity would also increase. Overall, there would be associated decreases in the magnitude of peak flows and decreases in total water yield and seasonal low flow.

Fuel build-up and stand conditions would continue to develop that increase the likelihood of large, stand-replacing wildfire. Areas affected by high-severity fire would experience increased peak flows. In the Middle Fork Mill Creek subwatershed, the spring rain-on-snow increase in the 2-year event compared to the existing condition is estimated to be 4.8 percent. Similarly for South Fork Mill Creek, the spring rain-on-snow increase in the 2-year event compared to the existing condition is estimated to be 5.3 percent. Outside the project area, assessment of harvest that may occur on NFS, state, and private lands within the North Fork Mill Creek subwatersheds indicates that increases in peak flows for would be about 7.5 percent. Because cumulative effects downstream within the mainstem Mill Creek are computed as area-weighted averages of the effects within the upstream subwatersheds, increases in 2-year peak flows within Mill Creek would be expected to be less than 10 percent. Short- to mid-term increases in 25-year peak flows would be lower. Assuming that severe wildfire does not affect substantially more than 40 percent of combined watershed area, adverse effects to stream channels and fish habitat, or flood damage, would not be expected to occur.

**4.5.3.2 Alternative B – Modified Proposed Action**

Under Alternative B, the short-term increase in the 2-year peak flow event above the existing condition is estimated to be 13.8 percent for the Middle Fork Mill Creek subwatershed, and 12.1 percent for the South Fork Mill Creek subwatershed. Harvest activity on state and private lands would be expected to increase 2-year peak flows by less than 1 percent in each subwatershed. Outside the project area, assessment of harvest that may occur on NFS, state, and private lands within the North Fork Mill Creek subwatershed indicates that increases in 2-year peak flows would be about 7.5 percent. Because cumulative effects downstream within the mainstem Mill Creek are computed as area-weighted averages of the effects within the upstream subwatersheds, effects within Mill Creek are predicted to be about 10.2 percent in the short- to mid-term. When compared to the HRV condition (more representative of conditions within which the areas channels have evolved), the 2-year peak flow predicted for Mill Creek is slightly less than that predicted for HRV. Short- to mid-term increases in 25-year peak flows would be lower. Total water yield and seasonal low flows would be expected to measurably increase above existing conditions within the Middle and South forks of Mill Creek, and may be measurable downstream from the project area within the mainstem Mill Creek.

Long-term, based on the observed response to past treatments in the project area, reductions in hydrologic maturity in the Middle and South Fork Mill Creek subwatersheds would be relatively short-term as forest canopy cover increases and reverts toward current conditions. As canopies develop in treated and untreated areas, hydrologic maturity would also increase. Overall, there
would be associated decreases in the magnitude of peak flows and decreases in total water yield and seasonal low flow.

4.5.3.3 Alternative C – Commercial Harvest without New Road Construction

Under Alternative C, the short-term increase in the 2-year peak flow event above the existing condition is estimated to be 11.3 percent for the Middle Fork Mill Creek subwatershed, and 9.7 percent for the South Fork Mill Creek subwatershed. Harvest activity on state and private lands would be expected to increase 2-year peak flows by less than 1 percent in each subwatershed. Outside the project area, assessment of harvest that may occur on NFS, state, and private lands within the North Fork Mill Creek subwatersheds indicates that increases in 2-year peak flows would be about 7.5 percent. Because cumulative effects downstream within the mainstem Mill Creek are computed as area-weighted averages of the effects within the upstream subwatersheds, effects within Mill Creek are predicted to be about 7.6 percent in the short-term to mid-term. When compared to the HRV condition (more representative of conditions within which the area’s channels have evolved) the 2-year peak flow predicted for Mill Creek is about 2.7 percent less than that predicted for HRV. Short-term increases in 25-year peak flows would be lower. Total water yield and seasonal low flows would be expected to measurably increase above existing conditions within the Middle and South forks of Mill Creek, and may be measurable downstream from the project area within the mainstem Mill Creek.

Long-term, based on the observed response to past treatments in the project area, reductions in hydrologic maturity in the Middle and South Fork Mill Creek subwatersheds would be relatively short-term as forest canopy cover increases and reverts toward current conditions. As canopies develop in treated and untreated areas, hydrologic maturity would also increase. Overall, there would be associated decreases in the magnitude of peak flows and decreases in total water yield and seasonal low flow.

4.6 Forest Plan Consistency

Post-harvest burning and other treatments under the modified proposed action would reduce the risk of high-severity stand-replacing wildfires and attendant decreases in canopy density that would produce substantial increases in peak streamflows, and that would likely result in damage to stream channels, fish habitat, and contribute to water quality degradation. Project scoping identified effects on streamflow regimes and peak flows as a cumulative effects concern affecting water quality and stream channels. The streamflow regime analysis reported within this Hydrology report is a cumulative effects analysis addressing both NFS and other ownerships.

The modified proposed action would also comply with the direction provided by INFISH (USDA 1995) by maintaining stream channel integrity, channel processes, and the sediment regimes (including the elements of timing, volume, and character of sediment input and transport) under which the riparian and aquatic ecosystems developed, and by providing instream flows to support healthy riparian and aquatic habitats, as well as the stability and effective function of stream channels and the ability to route flood discharges.

4.7 Unavoidable Adverse Impacts

Streamflow increases associated with extensive logging are unavoidable. These unavoidable effects are short-term and do not increase to a measurable degree relative to natural background conditions under the action alternatives.
4.8 Irretrievable or Irreversible Commitment of Resources

No irretrievable or irreversible commitments of resources related to streamflow were identified in any of the action alternatives.

CHAPTER V WATER QUALITY

The issue indicator used to evaluate water quality/stream impairment as indicated by potential change in Section 303(d) listing status is:

- Number of stream segments that would change per the State of Washington 303(d) listing status relative to that reported by the Washington Department of Environmental Quality reported at their total maximum daily load (TMDL) website.\(^{14}\)

5.1 Assessment Methods

This analysis examined all streams and processes that would affect water quality relative to 303(d) listing potential within the Middle and South Fork Mill Creek A to Z Project area.

The Washington Department of Ecology website (apps.ecy.wa.gov/wats/Default.aspx) was queried for listed waters within the project area. Segments listed within the Middle and South Fork Mill Creek A to Z Project area were noted, tabulated, and mapped.

Three stream segments within the project area are listed as impaired for bacteria. No other sources of impairment are listed.

Other than bacteria, water quality parameters within forest watersheds that are most commonly affected by forest practices are sediment and water temperature. Sediment was discussed earlier within this report. A number of other parameters—including pH, conductivity, dissolved oxygen, nitrogen, phosphorus, herbicides, and pesticides—have been studied widely but effects on these parameters have rarely been found to be substantial enough to limit designated uses of water in association with modern forest practices, including the use of buffer strips (MacDonald et al. 1991). These parameters are not further discussed. Fecal coliform bacteria appears as a water quality concern in some watersheds and is reviewed below, followed by a discussion of water temperature.

5.2 Current Conditions

Washington State’s 303(d) TMDL database currently notes three stream segments within the project area that are adversely affected by coliform bacteria (Washington Department of Ecology 2014) (Figure 53).

One segment previously listed for dissolved oxygen was removed from the list of impaired waters (Table 11).\footnote{www.ecy.wa.gov/programs/wq/303d/currentassessment.html} No stream segments are listed for other pollutants, including sediment or water temperature.

Under a 2000 Memorandum of Agreement (MOA) between US Forest Service Region 6 and the Washington State Department of Ecology (Ecology), the Forest Service is designated as the agency responsible for meeting the Clean Water Act (CWA) on NFS lands. Through this MOA, the Forest Service is responsible for ensuring that all waters on NFS lands meet or exceed water quality laws and regulations and that activities on NFS lands are consistent with protections provided in Washington Administrative Code and relevant state water quality requirements. The MOA recognizes the contribution of existing Forest Service direction, including INFISH and best management practices (BMP), in meeting water quality laws and regulations, and states that the Forest Service and Ecology will collaborate to address 303(d) listings through the development of TMDLs and Water Quality Implementation Plans, which have been completed for CNF lands (see http://www.ecy.wa.gov/programs/wq/tmdl/ColvilleNF.html).
5.3 Management Prescriptions

Management prescriptions for the project area were developed pursuant to the planning guidance outlined above in order to avoid or minimize potential for further degradation of water quality. No specific management prescriptions beyond those pursuant to the planning guidance were necessary.

5.4 Environmental Consequences

This section provides a detailed analysis of potential effects of the No Action and action alternatives related to stream impairment, as indicated by potential change in Section 303(d) listing status. This analysis addresses the effects of the modified proposed action and alternatives summarized in Chapter II of the final EA and described in detail in resource specialist reports. The analysis considers implementation of design elements described in Chapter II intended to avoid or minimize adverse impacts to water quality.

5.4.1 Literature Review

Fecal coliform bacteria are derived from the feces of humans and other warm-blooded animals. Fecal organisms enter stream systems through direct discharge from mammals and birds, from agricultural and storm runoff containing mammal and bird wastes, and from sewage discharge. Even though fecal coliform bacteria are not pathogenic, they occur along with pathogenic organisms and their presence indicates potential human health risk. In forested areas, high levels of coliform bacteria usually would be associated with inadequate waste disposal by recreational users, the presence of livestock or other animals in the stream channel or riparian zone, and poorly maintained septic systems (MacDonald et al. 1991).

The primary factor affecting stream temperature is the amount of sunlight reaching the stream surface, as affected by the shading provided by vegetation and topography (Brown and Krygier 1970; Brown 1969; Sullivan and Adams 1990; Theurer et al. 1984; Beschta and Weatherred 1984).

Riparian buffers effectively prevent solar radiation from reaching streams where they are sufficiently wide, and where vegetation is sufficiently tall and dense. Studies in western Oregon and Washington demonstrate that at least 80 percent of potential stream shade is produced within one-half of a tree height (0.5H) from the stream bank (Brosofske et al. 1997; Brazier and Brown 1973; Steinblums et al. 1984). Castelle and Johnson (2000) concluded that most of the potential shade comes from the riparian area within 75 feet of the channel. In a recent study conducted within 27 well-stocked stands in north central Idaho, Teply and McGreer (2013) found that most

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Table 11. Project-area stream segments listed in Washington State Waterbody Assessment

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Parameter and ID #</th>
<th>1996 category</th>
<th>2004 category</th>
<th>2008 category</th>
<th>2012 category</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Fork Mill Creek</td>
<td>Bacteria (8519)</td>
<td>Y</td>
<td>4A</td>
<td>4A</td>
<td>4A</td>
</tr>
<tr>
<td>Mill Creek</td>
<td>Dissolved Oxygen (37993)</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Fork Mill Creek</td>
<td>Bacteria (38004)</td>
<td>4A</td>
<td>4A</td>
<td>4A</td>
<td></td>
</tr>
<tr>
<td>Bestrom Creek</td>
<td>Bacteria (37942)</td>
<td>4A</td>
<td>4A</td>
<td>4A</td>
<td></td>
</tr>
</tbody>
</table>
shade was provided by trees within 25 feet of streambanks, and that partial cut harvest restricted to the outer 50 feet of 75-foot buffers reduced pre-harvest shade by an average of only 5 percent.

5.4.2 Direct and Indirect Effects

5.4.2.1 Analysis Indicators
The analysis indicators used to evaluate water quality/stream impairment as indicated by potential change in Section 303(d) listing status are:

- Increase in sediment delivery to streams above natural background
  
  This metric represents the potential for project activities to increase sediment delivery to streams from all project erosion source activities (roads, logging, fuel treatment, stream crossing culvert installations and removals) in relation to an estimate of natural background sediment delivery within three subwatersheds: Middle Fork Mill Creek; South Fork Mill Creek; Camp Creek.

- Decrease in stream shade from existing conditions
  
  This metric represents decrease in stream shade that potentially could occur due to project activities that disturb streamside vegetation.

- Increase in coliform bacteria contamination of streams
  
  This metric represents the potential for project activities to affect delivery of coliform bacteria to streams, with potential sources as noted earlier being inadequate waste disposal by recreational users, the presence of livestock or other animals in the stream channel or riparian zone, and poorly maintained septic systems.

Short-term effects to water quality were assessed for the period of time during project activities. Long-term effects were evaluated for the period of time after project activities.

5.4.2.2 Alternative A – No Action

5.4.2.2.1 Methods and Assumptions
Under Alternative A without fire, it is assumed that little to no change in existing effects upon project area streams related to sediment, stream shade, and coliform bacteria would occur, and no additional 303(d) listed stream segments would develop short- or long-term. With wildfire, it is assumed that processes affecting water quality may be adversely affected that could lead to additional 303(d) listings.

5.4.2.2.2 Direct and Indirect Effects
Under the No Action alternative and in the absence of wildfire, there would be no alteration of stand structure through activities that would occur under either action alternative. Several range improvement projects would continue to be implemented and maintained to harden stream crossings to reduce cattle damage and allow restoration of riparian areas. There would be little change in sediment delivery to streams. Riparian cover, and stream shade, would be maintained. Access to riparian areas and streams by cattle would remain more or less unchanged. Therefore, it is assumed that little to no short-term or long-term change in existing effects upon project area
streams related to sediment, stream shade, and coliform bacteria would occur, and no additional 303(d) listed stream segments would develop short- or long-term. Under Alternative A with wildfire, substantial changes to existing effects upon project area streams may occur: sediment delivery to streams would substantially increase due to soil erosion and mass wasting, some of which may originate from within INFISH RHCA boundaries; riparian area vegetation would be destroyed along some stream reaches, resulting in loss of stream shade and increased water temperature well above Washington state water quality standards criteria; and cattle could have increased access to riparian areas and streams and increased time within streams, which could increase levels of bacteria. All of these potential effects of wildfire could result in the addition of multiple 303(d) listed stream segments, short-term. Over time, as watershed conditions recover, wildfire effects would diminish and this could lead to delisting of streams, long-term.

5.4.2.3 Alternatives B and C – Action Alternatives

Project effects on water quality would mostly occur from road systems, commercial timber harvest and shaded fuel break treatments, post-harvest fuel treatment and, to a much smaller degree, culvert installation and removal. These are addressed in Commercial Harvest Effects. Effects of other project activities are discussed in Effects Common to Both Action Alternatives.

5.4.2.3.1 Commercial Harvest Effects

Methods and Assumptions

Potential effects of project activities on the likelihood of additional 303(d) listed stream segments for sediment were assessed via the sediment modeling and budgeting results discussed at Section III.

Potential effects of project activities on the likelihood of additional 303(d) listed stream segments for water temperature were assessed by interpretation of the potential effects of commercial harvest, shaded fuel break treatments, and road construction activities near streams.

Potential effects of project activities on the likelihood of additional 303(d) listed stream segments for bacteria were assessed by interpretation of the potential effects of project activities on access to riparian areas and streams by cattle.

Direct and Indirect Effects

Alternative B – Modified Proposed Action

Commercial Harvest

Analysis of stream sediment delivery indicates that the combined effects of commercial harvest, shaded fuel breaks, road maintenance and reconstruction, road construction and road improvement projects would decrease sediment delivery to project area streams (Section III). Under Alternative B, a total of 11,021 acres of commercial harvest would occur. Commercial harvest would not be located within INFISH RHCA boundaries. Minimum width of INFISH RHCA buffers along perennial streams is 110 feet within the project area, and based on Teply and McGreer (2013), no decrease in stream shade would occur. Harvest along non-perennial streams does not affect summer water temperatures, and not downstream within perennial waters (Brown 1980). Harvest outside INFISH RHCA would not be expected to increase cattle access to streams; however, mitigation measures have been proposed to monitor post-harvest cattle movement, and
mitigation measures would be employed if needed. Additional 303(d) listings by Washington State are not expected in the short-term or long-term.

Temporary Road Construction
19 miles of temporary road construction would occur. 0.9 miles would be constructed within INFISH RHCA. Because road construction would only minimally occur within INFISH RHCA, and these INFISH RHCA have been demonstrated to be highly effective at preventing sediment associated with logging or roads from passing through them, increases in sediment delivery from new roads would be expected to be minor (Megahan and Ketcheson 1996; Ketcheson and Megahan 1996; King 1979). No increase in mass wasting activity is expected. No changes in grazing management activities would occur; however, mitigation measures have been proposed to monitor post-harvest cattle movement and mitigation measures would be employed if needed. Road construction within INFISH RHCA could cause minor localized loss of stream shade, but not to the degree that detectable increases in water temperature would occur. Assessment of these effects indicates that no additional 303(d) listed stream segments would occur.

Fuel Treatment
Fuel treatment by piling and burning or broadcast burning is predicted to increase sediment delivery following commercial harvest and shaded fuel break treatments. However, WEPP:FuME analysis of stream sediment delivery demonstrates that fuel treatment would deliver relatively minor amounts of sediment to project area streams (Section III). Fuel treatment would not occur within INFISH RHCA, and no effects upon stream shade would normally be expected. However, if fire inadvertently affects trees within INFISH RHCA, some local shade loss could occur, but detectable increases in water temperature would be unlikely, and temporary. Increased cattle access to streams would not be expected; however, mitigation measures have been proposed to monitor post-harvest cattle movement and mitigation measures would be employed if needed. Assessment of these effects indicates that no additional 303(d) listed stream segments would occur.

Alternative C – Commercial Harvest without New Road Construction
Potential effects on water quality with implementation of Alternative C are essentially the same as discussed for Alternative B, although with fewer acres of commercially harvest and fuel treatment, and less potential effect. No temporary roads would be constructed with Alternative C. No additional 303(d) listed stream segments would occur.

5.4.2.3.2 Effects Common to Both Action Alternatives

Methods and Assumptions
Potential effects of project activities on the likelihood of additional 303(d) listed stream segments for sediment were assessed via the sediment modeling and budgeting results discussed at Section III.

Potential effects of project activities on the likelihood of additional 303(d) listed stream segments for bacteria were assessed by interpretation of the potential effects of project activities on access to riparian areas and streams by cattle.
Direct and Indirect Effects

Road Reconstruction and Maintenance
Road maintenance is planned on about 18 miles of county and 65 miles of NFS roads. Sediment delivery associated with haul-traffic is covered in Commercial Harvest Effects below. Sediment delivery associated with reconstruction and maintenance activities are described in Section III and are expected to be negligible overall. Although not modeled, short-term increases in sediment delivery to some smaller tributary streams could occur due to road-related activities. However, based on the location and extent of project activities, it is highly unlikely that sediment delivery due to project activities would exceed the 50% percent increase above natural threshold where instream effects may be detectable, and would not be expected to lead to 303(d) listings by Washington State.

Road reconstruction and maintenance is not expected to disturb vegetation along roads that currently provide shade to streams, and would not be expected to lead to 303(d) listings by Washington State for water temperature.

Reconstruction of NFS Road 9411175 may decrease trailing along Hanson Creek. Otherwise, road maintenance is not expected to increase cattle access to streams. Overall, this action would not be expected to lead to additional 303(d) listings by Washington State for bacteria.

Development of borrow pits
As many as 15 borrow pits may be developed. Development of borrow pits would create some degree of erosion, but because they are located remote from streams, sediment delivery is unlikely. Similarly, because proposed borrow pits are located remote from streams, decreased stream shade and increased access to streams by cattle associated with borrow pits is unlikely. This action would not be expected to lead to 303(d) listings by Washington State.

System road decommissioning
As many as 7.7 miles of system roads may be decommissioned. In some cases because of poor road location (e.g., where located adjacent to streams), road decommissioning is proposed specifically to reduce sediment delivery (see Section III). As decommissioned roads recover and return to forest productivity, shade may increase as road surfaces re-forest, and in some instances, cattle access may decrease as vegetation ingrowth becomes a barrier to cattle movement. Additional 303(d) listings by Washington State are not expected.

Shaded fuel breaks
Shaded fuel breaks may be developed on as many as 462 acres. Because effects of shaded fuel breaks on sediment delivery are similar to those from commercial harvest activities, sediment delivery effects were addressed in Commercial Harvest Effects. Shaded fuel breaks are not located within RHCAs, except upslope of existing roads in upland vegetation, and as a result would not be expected to decrease stream shade. Removal of trees outside RHCAs is not expected to increase cattle access to streams; however, mitigation measures have been proposed to monitor post-harvest cattle movement, and barriers would be installed if needed. Additional 303(d) listings by Washington State are not expected.

Precommercial thinning
Precommercial thinning activities are planned on as many as 836 acres. Because precommercial thinning is done by hand and without ground-disturbing machinery, no erosion and sediment
delivery would occur. Precommercial thinning units are not located within RHCAs, and as a result would not be expected to decrease stream shade. Removal of trees outside RHCAs is not expected to increase cattle access to streams; however, mitigation measures have been proposed to monitor post-harvest cattle movement and barriers would be installed if needed. Additional 303(d) listings by Washington State are not expected.

**Redefinition of pileated woodpecker core area**
Redefinition of pileated woodpecker core area may affect as many as 190 acres. Redefinition of pileated woodpecker core area would not entail canopy removal or ground-disturbing activities and would not be expected to affect sediment delivery, stream shade or cattle access. Additional 303(d) listings by Washington State are not expected.

**Fish passage structure replacement and removal**
As many as 17 fish passage structures may be replaced or removed. Fish passage structure replacement and removal is expected to increase sediment delivery short-term below the crossing sites (Foltz et al. (2008), but the long-term benefits would be a reduction in risk of erosion and sediment production and delivery associated with culvert failure resulting in washout of all or part of the local road prism. Local and very limited removal of vegetation could decrease stream shade at some locations, but would not be expected to measurably affect water temperature. Since these are existing crossings, cattle access at affected stream crossings would not be expected to change. Additional 303(d) listings by Washington State are not expected.

**Rehabilitation of areas impacted by user-created trails**
As many as 2.8 acres may be affected by rehabilitation of user-created trails. Rehabilitation of areas impacted by user-created trails may accelerate recovery of disturbed surfaces subject to erosion, and could result in small decreases in sediment delivery. This activity is located in an RHCA, and may result in an increase in stream shade and may decrease cattle access. Additional 303(d) listings by Washington State are not expected.

**Designation of NFS roads open to all vehicles**
NFS roads 7018000 and 9411130 would be re-designated. Designation of NFS roads open to all vehicles would not affect sediment delivery, stream shade, or cattle access. Additional 303(d) listings by Washington State are not expected.

**Tree Planting**
Tree planting would occur on as many as 198 acres following seed tree harvest. Sediment delivery, stream shade, and cattle access would not be affected by tree planting. Additional 303(d) listings by Washington State are not expected.

**5.4.3 Cumulative Effects**
Cumulative effects related to water quality are the incremental impacts of an alternative when added to the effects of other past, present, and reasonably foreseeable future actions. See Appendix A of the final EA for a summary of all past, present, and reasonably foreseeable future actions in the project area.

Geographic Scope - The cumulative effects analysis area includes the portion of Mill Creek watershed including North Fork Mill Creek, Middle and South Fork Mill Creek, Grevit Creek, and Camp Creek subwatersheds, and Mill Creek immediately downstream of the confluence of
the South and North Fork subwatersheds. Although parts of the Clugston Creek, Onion Creek, Squaw Creek, Amazon Creek and Narcisse Creek subwatersheds are within the project area, only small areas of these subwatersheds lie within project boundaries and only small parts of these subwatersheds are treated under the project alternatives; they are not included in the cumulative effects analysis area.

Temporal Scope - The timeframe for cumulative effects analysis is thirty years into the future, approximately the timeframe anticipated for re-entry into the project area to address changes in stand structure resulting from proposed treatments and stand development. Cumulative effects on water quality in the future would mostly occur through timber harvest, road construction, rural residential use, dispersed recreation, and cattle grazing.

Past Actions - Nearly the entire cumulative effects analysis area was regenerated by stand-replacing fires in the 1920s. Wildfire likely led to increases in sediment delivery to streams and decreases in stream shade in the cumulative effects analysis area. Past activities occurring in the cumulative effects analysis area that may have had additional effects on water quality include wildfire suppression, timber harvest, road construction, dispersed recreation, livestock grazing, and conversion of forest lands to pasture and other non-forest land uses (e.g., rural residential development and transmission line corridor construction). The effects of wildfire and past activities in the cumulative effects analysis area subwatersheds are reflected in existing water quality conditions.

Present and Reasonably Foreseeable Actions - Wildfire suppression, timber harvest, road construction, rural residential use, transmission line corridor maintenance, dispersed recreation, and livestock grazing are ongoing and are anticipated to be the reasonably foreseeable future actions in the cumulative effects analysis area. Actions in the project area are documented in Appendix A of the final EA. Actions outside the project area are also described below. Cumulative effects on sediment delivery during this timeframe would mostly occur through vegetation treatments. While wildfire suppression would continue to occur, it is not possible to predict when and where these actions may overlap with the effects of the proposed project.

Within the project area, a review of Washington Forest Practice applications (WaDNR 2016) on state and private lands in the project area indicates ongoing and future plans for 274 acres of uneven-aged harvest, 213 acres of even-aged harvest, and less than 0.1 miles of new road construction. Effects of timber harvest and road construction on state and private lands in the project area would be mitigated by Washington State Forest Practice Rules designed to limit adverse impacts to water quality from these activities. Livestock grazing would continue to occur on two NFS grazing allotments, as well as on non-NFS lands. Dispersed recreation would continue, with limited impacts to water quality. The footprint of rural residential development is not expected to increase in the project area. There are no other known planned major developments or land use changes that would alter disturbance patterns in the project area.

Outside the project area, the Colville National Forest is implementing the North Fork Mill Creek A to Z Project which involves commercial harvest, fuel hazard reduction, precommercial thinning, road reconstruction and maintenance, and habitat restoration at levels comparable to that under the modified proposed action, on a per-acre basis. A review of Washington Forest Practice Applications indicates that timber harvest and road construction on state and private lands are also anticipated to occur at levels comparable to those in the Middle and South Fork Mill Creek A to Z Project area. Effects of timber harvest and road construction on state and private lands outside the project area would be mitigated by Washington State Forest Practice Rules designed
to limit adverse impacts to water quality from these activities. Livestock grazing on NFS lands would continue on one grazing allotment, as well as on non-NFS lands within the North Fork Mill Creek subwatershed. The footprint of rural residential development is and transmission line corridors is not expected to increase. There are no other known planned major developments or land use changes that would alter disturbance patterns in the cumulative effects analysis area.

In the Middle and South Fork Mill Creek subwatersheds, current grazing levels would continue under Allotment Management Plans (AMPs) that incorporate new management practices, standards, and mitigations based on current laws, regulations, and policies of the Forest Service. Allotment Operating Instructions would continue to be used to adaptively manage on a year-to-year basis within the intent of the AMPs and in response to monitoring results. Existing range improvements would continue to be maintained. Several range improvement projects would continue to be implemented and maintained to harden stream crossings in order to reduce cattle damage and allow restoration of riparian areas. Water quality effects of grazing on non-NFS lands are not expected to change.

In the North Fork Mill Creek subwatershed, the total amount of sediment introduced into stream systems as a result of ongoing livestock grazing of the 33 cow/calf pairs on the North Fork Mill, Strauss, and Rodgers pastures on NFS lands within the project area is expected to continue to decrease. This would occur as grazing management allows riparian vegetation to become reestablished and any overgrazed areas to recover. Fecal coliform levels would continue to be reduced enough to meet Washington State water quality standards. Water temperatures as affected by grazing are expected to continue to remain unchanged or improve as grazing management allows riparian vegetation to become reestablished, and would continue to meet state standards. Water quality effects of grazing on non-NFS lands are not expected to change.

5.4.3.1 Alternative A – No Action

Sediment delivery – The cumulative effects of the No Action alternative on sediment delivery are summarized in the Sediment Delivery section earlier in this chapter. The effects of the No Action alternative without wildfire, combined with the effects of other past, present, or reasonably foreseeable future actions would result in a decrease in sediment delivery downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek. It is highly unlikely that sediment delivery due to combined effects project activities and other past, present, and reasonably foreseeable future activities would exceed the 50 percent increase above natural threshold where instream effects may be detectable (WFPB 2011), and would not be expected to lead to 303(d) listings by Washington State.

Stream shade - Under the No Action alternative and in the absence of wildfire, there would be no alteration of stand structure. Riparian cover, and stream shade and temperature, would be maintained. On non-NFS lands in the cumulative effects analysis area, even-aged and uneven-aged timber harvest activities are ongoing or planned. Timber harvest activities on non-NFS lands would follow Washington State Forest Practice Rules designed to limit adverse impacts to stream shade and temperature, including cumulative impacts. Vegetation treatments associated with the North Fork Mill Creek A to Z Project would not occur within INFISH RHCAs, leading to no changes in stream shade protection of stream temperatures. Localized tree removal would occur along streams, but detectable increases in water temperature would be unlikely, and temporary, if they occur. Because there would be no detectable change in stream shade or stream temperature under the No Action alternative and as a result of other past, present, and reasonably foreseeable future activities within the cumulative effects analysis area, there would therefore be no cumulative effects.
Coliform bacteria - Under the No Action alternative, livestock grazing would continue on NFS lands in the project area with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Livestock grazing would also continue on NFS lands in the North Fork Mill Creek subwatershed with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Project activities under the North Fork Mill Creek A to Z Project are not expected to increase cattle access to riparian areas and streams. However, removal of an informal latrine along North Fork Mill Creek would occur and associated improvements in fecal coliform levels would occur as well. Livestock grazing along private lands in the cumulative effects analysis area would also likely continue with no change in effects to water quality. Therefore, given these improvements and protections, cumulative effects on fecal coliform bacteria downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek within the cumulative effects analysis area would be expected to improve.

Wildfire scenario - Without vegetation treatment, the chance for stand-replacing wildfire and uncharacteristic disturbance increases under Alternative A. With wildfire, it is assumed that processes affecting water quality may be adversely affected and could lead to additional 303(d) listings within the project area for reasons described above. However, whether or not these increases would lead to water quality impairment downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek depends on the location, size, and intensity of the wildfire. Cumulative effects on sediment delivery, stream temperature, and coliform bacteria downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek could lead to 303(d) listings by Washington State.

5.4.3.2 Alternative B – Modified Proposed Action

Sediment delivery – The cumulative effects of the modified proposed action on sediment delivery are summarized in the Sediment Delivery section earlier in this chapter. The effects of Alternative B, combined with the effects of other past, present, or reasonably foreseeable future actions would result in a decrease in sediment delivery downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek. It is highly unlikely that sediment delivery due to combined effects of project activities and other past, present, and reasonably foreseeable future activities would exceed the 50 percent increase above natural threshold where instream effects may be detectable (WFPB 2011), and would not be expected to lead to 303(d) listings by Washington State.

Stream shade - Under Alternative B, there would be limited alteration of stand structure within INFISH RHCAs. Riparian cover, and stream shade and temperature, would be maintained on nearly all streams. Localized tree removal would occur along streams, but detectable increases in water temperature would be unlikely, and temporary, if they occur. On non-NFS lands in the cumulative effects analysis area, even-aged and uneven-aged timber harvest activities are ongoing or planned. Timber harvest activities on non-NFS lands would follow Washington State Forest Practice Rules designed to limit adverse impacts to stream shade and temperature, including cumulative impacts. Vegetation treatments associated with the North Fork Mill Creek A to Z Project would not occur within INFISH RHCAs, leading to no changes in stream shade protection of stream temperatures. Localized tree removal would occur along streams, but detectable increases in water temperature would be unlikely, and temporary, if they occur. Because there would be no detectable change in stream shade or stream temperature under the modified proposed action and as a result of other past, present, and reasonably foreseeable future activities within the cumulative effects analysis area, there would therefore be no increases in stream
temperature downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek that would be expected to lead to 303(d) listings by Washington State.

Coliform bacteria - Under the modified proposed action, livestock grazing would continue on NFS lands in the project area with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Project activities are not expected to increase cattle access to riparian areas and streams. Livestock grazing would also continue on NFS lands in the North Fork Mill Creek subwatershed with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Project activities under the North Fork Mill Creek A to Z Project are not expected to increase cattle access to riparian areas and streams. However, removal of an informal latrine along North Fork Mill Creek would occur and associated improvements in fecal coliform levels would occur as well. Livestock grazing along private lands in the cumulative effects analysis area would also likely continue with no change in effects to water quality. Therefore, given these improvements and protections, cumulative effects on fecal coliform bacteria downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek within the cumulative effects analysis area would be expected to improve. Under Alternative B, there would be no reason for additional listing of streams for water quality impairment under the Clean Water Act.

Design elements for this Project and for the North Fork Mill Creek A to Z Project would be employed to monitor for any project impacts to grazing management. Unintended impacts to cattle movement resulting from implementation of these projects, and unintended impacts to resources that could result, would be addressed adaptively. The intent is to avoid, minimize, or otherwise mitigate adverse impacts to affected resources, including to water quality.

5.4.3.3 Alternative C – Commercial Harvest without New Road Construction

Sediment delivery – The cumulative effects of Alternative C on sediment delivery are summarized in the Sediment Delivery section earlier in this chapter. The effects of Alternative C, combined with the effects of other past, present, or reasonably foreseeable future actions would result in a decrease in sediment delivery downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek. It is highly unlikely that sediment delivery due to combined effects project activities and other past, present, and reasonably foreseeable future activities would exceed the 50 percent increase above natural threshold where instream effects may be detectable (WFPB 2011), and would not be expected to lead to 303(d) listings by Washington State.

Stream shade - Under Alternative C, there would be limited alteration of stand structure within INFISH RHCAs. Riparian cover, and stream shade and temperature, would be maintained on nearly all streams. Localized tree removal would occur along streams, but detectable increases in water temperature would be unlikely, and temporary, if they occur. On non-NFS lands in the cumulative effects analysis area, even-aged and uneven-aged timber harvest activities are ongoing or planned. Timber harvest activities on non-NFS lands would follow Washington State Forest Practice Rules designed to limit adverse impacts to stream shade and temperature, including cumulative impacts. Vegetation treatments associated with the North Fork Mill Creek A to Z Project would not occur within INFISH RHCAs, leading to no changes in stream shade protection of stream temperatures. Localized tree removal would occur along streams, but detectable increases in water temperature would be unlikely, and temporary, if they occur. Because there would be no detectable change in stream shade or stream temperature under Alternative C and as a result of other past, present, and reasonably foreseeable future activities within the cumulative effects analysis area, there would therefore be no increases in stream temperature downstream
from the North and South forks of Mill Creek within the mainstem of Mill Creek that would be expected to lead to 303(d) listings by Washington State.

Coliform bacteria - Under Alternative C, livestock grazing would continue on NFS lands in the project area with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Project activities are not expected to increase cattle access to riparian areas and streams. Livestock grazing would also continue on NFS lands in the North Fork Mill Creek subwatershed with improved grazing practices that are intended to decrease fecal coliform bacteria levels. Project activities under the North Fork Mill Creek A to Z Project are not expected to increase cattle access to riparian areas and streams. However, removal of an informal latrine along North Fork Mill Creek would occur and associated improvements in fecal coliform levels would occur as well. Livestock grazing along private lands in the cumulative effects analysis area would also likely continue with no change in effects to water quality. Therefore, given these improvements and protections, cumulative effects on fecal coliform bacteria downstream from the North and South forks of Mill Creek within the mainstem of Mill Creek within the cumulative effects analysis area would be expected to improve. Under Alternative C, there would be no reason for additional listing of streams for water quality impairment under the Clean Water Act.

Design elements for this Project and for the North Fork Mill Creek A to Z Project would be employed to monitor for any project impacts to grazing management. Unintended impacts to cattle movement resulting from implementation of these projects, and unintended impacts to resources that could result, would be addressed adaptively. The intent is to avoid, minimize, or otherwise mitigate adverse impacts to affected resources, including to water quality.

5.5 Forest Plan Consistency

FSM 2532 provides policy and direction specific to water quality management on NFS lands. Approved BMPs would be applied to all management activities as the method for control of nonpoint sources of water pollution, and for compliance with established state or national water quality goals as directed by the FP. Applied BMPs would be based on site-specific conditions and political, social, economic, and technical feasibility.

The project would comply with State requirements in accordance with the federal Clean Water Act for protection of waters of the State of Washington through planning, application, and monitoring of best management practices in conformance with the Clean Water Act regulations and federal guidance and the Colville National Forest Land and Resource Management Plan.


There is no expected detrimental effect with respect to bacteria as a result of project actions.

Using the design elements best management practices described in Chapter II of the final EA, water quality would not be detrimentally impacted by the modified proposed action. No additional stream segments would be added to the 303(d) list of impaired waters.
Consistency of the proposed activities described above with Forest Plan elements for other resources are described in resource specialist reports accompanying the EA and located in the project file.

5.6 Unavoidable Adverse Impacts

No unavoidable adverse impacts to water quality were identified in any of the alternatives.

5.7 Irretrievable or Irreversible Commitment of Resources

No irretrievable or irreversible commitments of resources related to water quality were identified in any of the alternatives.

REFERENCES


Burroughs, E. R., Jr. and J. G. King. 1985. Surface erosion control on roads in granitic soils. Pages 183 to 190 in: Proceedings of ASCE Symposium, Sponsored by the Committee on Watershed Management/Irrigation and Drainage Division; April 30 to May 1, 1985, Denver, CO.


APPENDICES

Appendix A – Stream Demarcation

See compressed folder StreamDemarc_20151023.zip

Appendix B – WEPP:Road Field Data and Model Output

See Excel file WEPProad_fielddata_modelinput.xls

See PDF file WEPProad_prismclimate.pdf

Appendix C – WEPP:Road Summary Worksheets

See Excel file Sedbudget_CampCreek_20160301.xls

See Excel file Sedbudget_MiddleFork_20160226.xls

See Excel file Sedbudget_SouthFork_20160301.xls

Appendix D – WEPP:FuME Model Output

See compressed folder FuME_modeloutputfiles.zip

Appendix E – WEPP:FuME Summary Worksheets

See Excel file MFkandSFkandCamp_WEPPFuME_results.xls

Appendix F – Peak Flow Summary Worksheets

See Excel file MFkandSFkandCamp_peakflow_results.xls