United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
Central Washington Field Office
215 Melody Lane, Suite 119
Wenatchee, WA 98801

September 8, 2011

In Reply Refer To:
USFWS Reference: 13260-2011-F-0093
Hydrologic Unit Codes: 17-03-00-01-02
RE: Teanaway River Bank Protection Project

Roylene Rides-at-the-Door
Washington State Conservationist
Natural Resources Conservation Service
2021 E. College Way, Suite 206
Mount Vernon, Washington 98273-2373

Dear Ms. Rides-at-the-Door:

This correspondence transmits the U.S. Fish and Wildlife Service's (Service) Biological Opinion (BO) based upon our review of the proposed Teanaway River Bank Protection Project (Project). The attached BO describes the effects of the Project on the bull trout (*Salvelinus confluentus*) and designated critical habitat for the bull trout in accordance with Section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.). The July 1, 2011, cover letter and final Biological Assessment (BA) for this Project were received in the Service's Central Washington Field Office (CWFO) on July 5, 2011. The complete record for this consultation is on file in the CWFO.

The attached BO describes the effects of the Project on the bull trout and its designated critical habitat. The Service concludes in the attached BO that implementation of the Project is not likely to jeopardize the continued existence of the bull trout and will not result in the destruction or adverse modification of designated critical habitat for the bull trout.

If you have further questions about this BO or your responsibilities under the Act, please contact Gregg Kurz of the CWFO in Wenatchee at 509-665-3508.

Sincerely,

Jessica L. Gonzales for

Ken S. Berg, Manager
Washington Fish and Wildlife Office

Attachment

BIOLOGICAL OPINION

for the

NRCS – Teanaway River Bank Protection Project

Department of Agriculture
Natural Resources Conservation Service
2021 E. College Way, Suite 206
Mount Vernon, Washington 98723-2373

USFWS Reference Number: 13260-2011-F-0093

Hydrologic Unit Code: 17-03-00-01-02, Teanaway River

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Issued by: Jessica L. Gonzales for Date Sept 8, 2011

Ken S. Berg, Manager
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EXECUTIVE SUMMARY

The purpose of the Teanaway River Bank Protection Project (Project) is to stabilize the shoreline of the Teanaway River, eliminating the potential for significant erosion of the shoreline and subsequent loss of agricultural lands. Active erosion has been observed over the past 2 years, which has resulted in significant inputs of fine material into the Teanaway River and a significant loss to adjacent agricultural lands. The proposed project would construct a new channel with a radius of curvature to width ratio between 2.9 ft/ft and 4.7 ft/ft, which is within the range for a stable natural channel. Without the proposed project, the unstable meander of the river will continue to erode the shoreline, mobilizing large quantities of sediment and destroying the existing agricultural lands. The Project consists of constructing approximately 750 feet of new river channel and an overflow bench. To establish and maintain the contour and dimensions, rock vanes and wood structures will be constructed along the left bank of the river. Riparian vegetation will be planted on 1.9 acres of the left bank overflow bench and portions of the landowner's hay field. In all, the overflow bench, structural components, and riparian vegetation will serve to promote riparian and in-stream habitat. The Project is located in a bull trout migratory corridor, and is anticipated to affect individual bull trout from the Yakima core area. Direct effects to bull trout are expected to be minor. These changes are not likely to impair the population trend of the Yakima core area. Beneficial effects are anticipated due to decreased sediment input and increased riparian vegetation at the Project site. Based on our review and analysis, it is the Service's biological opinion that the Project, as proposed, is not likely to jeopardize the continued existence of the coterminous U.S. population of bull trout, and is not likely to destroy or adversely modify designated critical habitat for the bull trout. The Incidental Take Statement accompanying this biological opinion includes mandatory Reasonable and Prudent Measures and Terms and Conditions intended to minimize this incidental take. Advisory conservation recommendations are also provided to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information useful to the Natural Resources Conservation Service (NRCS) and Service for future consultations.

INTRODUCTION

The NRCS proposes to restore the river channel and floodplain along a portion of the Teanaway River that was disrupted by flooding in January 2009. The NRCS proposes to stabilize the shoreline on the subject property by removing previously completed, unpermitted shoreline work and stabilizing the existing shoreline with a combination of hard and soft stabilization measures. The proposed Project would result in the establishment of additional riparian vegetation along the Teanaway River, Kittitas County, Washington. The design, produced by NRCS, calls for stabilizing about 750 lineal feet of eroding riverbank by reconfiguring the existing channel, constructing rock vanes with embedded logs, installing several large log structures, creating an overflow bench that transitions to the adjoining agricultural field, and establishing native plantings. The work area will be isolated by a gravel-bag cofferdam. Instream work is expected to take up to 2 weeks to complete, and will occur during the low flow period to minimize encroachment on the wetted channel. Total construction time estimated for the Project is two months.

The proposed Project consists of four basic work elements: (1) installation of temporary erosion and sediment control measures, (2) channel reconfiguration and overflow bench grading, (3) installation of large woody debris and rock vane elements, and (4) re-vegetating the area disturbed during construction and additional riparian plantings. All of the work elements of the proposed Project have the potential to impact bull trout and their habitat, especially the "sediment," "embeddedness", "streambank condition," and "riparian reserve" indicators of habitat quality. In consultation with the Service, the NRCS reached the determination of "may affect, likely to adversely affect" the bull trout and its designated critical habit for the proposed Project, triggering formal consultation and the completion of this biological opinion. The proposed action includes provisions that are likely to be effective in minimizing Project effects on the bull trout and its habitat.

The U.S. Fish and Wildlife Service's (Service) objectives for the following biological opinion (BO) are (1) to determine whether the proposed Project is likely to "jeopardize the continued existence" of the bull trout (*Salvelinus confluentus*), and (2) to determine if the proposed project will destroy or adversely modify designated critical habitat for the bull trout. The standards for determining jeopardy are described in Section 7(a)(2) of the Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 *et seq.*) and further defined in 50 C.F.R. 402.14. Regarding critical habitat, this Biological Opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete our adverse modification analysis and determination.

Jeopardy Determination

The Service's jeopardy determination for bull trout relies on four components of analysis. (1) The *Status of the Species* evaluates the species' range-wide condition, the factors responsible for that condition, and the species' survival and recovery needs. (2) The *Environmental Baseline* evaluates the condition of the species in the action area, the factors responsible for that condition, and the role of the action area in the species' survival and recovery. (3) The *Effects of the Action* determines the direct and indirect impacts of the proposed Federal action and the effects of any

interrelated or interdependent activities on the species. Finally, (4) *Cumulative Effects* evaluates the effects of future, non-Federal activities in the action area on the bull trout.

In accordance with the implementing regulations for Section 7 of the Act and Service policy, the jeopardy determination is made by integrating these components. The integration begins with combining the effects of the proposed Federal action with the aggregated effects of everything that has led to the listed species' current status. This aggregation includes consideration of non-Federal activities in the action area that are likely to affect listed species in the future. The Service uses this assessment of aggregated effects to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery in the wild of the affected listed species.

To facilitate jeopardy analysis and recovery planning for wide-ranging species, the Service sometimes defines interim recovery units. Interim recovery units were defined in the final listing rule for the bull trout in November 1999 (64 FR 58910). We use these interim recovery units to guide consultation analyses and recovery efforts until a final recovery plan is developed. Pursuant to Service policy, when an action impairs or precludes the capacity of a recovery unit to provide both the survival and recovery functions assigned to it, that action may represent jeopardy to the species. When using this type of analysis, the biological opinion describes how the action affects not only the recovery unit's capability, but also the relationship of the recovery unit to both the survival and recovery of the listed species as a whole.

The jeopardy analysis for bull trout in this BO uses this approach. This analysis begins with a consideration of the role of the action area and the Yakima core area in the function of the Columbia River interim recovery unit. This functional assessment provides context for evaluating the effects of the proposed Federal action, combined with other relevant effects, on the survival and recovery of the bull trout within the coterminous United States.

Adverse Modification Determination

In accordance with policy and regulation, the adverse modification analysis in this BO relies on four components: (1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the bull trout in terms of primary constituent elements (PCEs), the factors responsible for that condition, and the intended recovery function of the critical habitat overall; (2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the Action Area, the factors responsible for that condition, and the recovery role of the critical habitat in the Action Area; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the PCEs and how that will influence the recovery role of affected critical habitat units; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the Action Area on the PCEs and how that will influence the recovery role of affected critical habitat units.

For the purpose of making the adverse modification determination, we evaluate the significance of effects of the proposed Federal action, along with any cumulative effects, on the functionality of bull trout critical habitat. We do this evaluation in the context of the rangewide condition of critical habitat and the role of the Action Area relative to the rangewide recovery function of critical habitat. Our objective is to determine if critical habitat rangewide would remain capable of serving its intended recovery function for the bull trout, or retain its current capacity for the PCEs to be functionally established in areas of currently unsuitable but capable habitat.

This BO is based upon information provided in the final Project Biological Assessment (BA) and numerous documents about bull trout, including previous biological opinions, published literature, and unpublished reports. A complete record of this consultation is on file in the Service's Central Washington Field Office in Wenatchee, Washington.

CONSULTATION HISTORY

The following chronology documents key points of the consultation process that culminated in the following biological opinion for the bull trout.

1. June 10, 1998: The Service issued a Final Rule listing Klamath and Columbia River distinct population segments (DPS) of bull trout as threatened species. This listing was superseded on November 1, 1999, when the Service listed the bull trout as threatened throughout the coterminous United States (64 FR 58910). While the coterminous listing had the effect of combining all DPSs into a single listed entity, the former DPSs were retained as "interim recovery units" for the purposes of section 7 consultation.
2. November 9, 2002: The Service published a Federal Register Notice proposing designation of critical habitat for the Klamath River and Columbia River DPSs of bull trout (USDI 2002, 61 FR 71236).
3. October 6, 2004: The Service published a Final Rule designating critical habitat for the Columbia River DPS of the bull trout. This final rule was remanded to the Service, and a revised final rule was published on September 26, 2005. This final rule excluded all areas that were proposed as critical habitat for bull trout in the upper Columbia River basin, including the action area (70 FR 56212).
4. January 14, 2010: The Service proposed to re-designate bull trout critical habitat throughout its range, with a final rule anticipated by October 2010 (75 FR 2270).
5. November 17, 2010, revised bull trout critical habitat became effective.
6. June 07, 2011: NRCS submitted a biological assessment and requested formal consultation on the Project.
7. July 05, 2011: The Service received additional clarifications from the NRCS regarding implementation of the proposed action.

BIOLOGICAL OPINION

1 PROJECT DESCRIPTION

The project description provided here is an abbreviated summary. For a more detailed description of the proposed action, please refer to the Project BA. The Project area occurs along roughly 750 lineal feet of the left streambank of the Teanaway River, about 4.5 miles upstream of the confluence with the Yakima River. The NRCS proposes an action that will be constructed over the course of about 8 weeks during the fall of 2011. Based on the characterization of the Project presented in the BA, the Service analyzed this Project in terms of 4 elements:

1. ***Installation of Temporary Erosion and Sediment Control Measures***
   The primary temporary erosion and sediment control (TESC) measure will consist of a cofferdam of 1 yd^3 super sacks full of gravel placed by an excavator on shore to isolate the work area and minimize sediment discharge to the stream. Fish exclusion and removal BMPs will be implemented before cofferdam placement. Construction will occur during low flow.

   Water behind the cofferdam will be pumped out and dispersed to an area of upland vegetation, where it would naturally infiltrate. Fish exclusion and relocation will be performed as needed by trained biologists using NOAA Fisheries electrofishing guidelines and requirements (NMFS 2000), or any other fish exclusion and relocation approach approved by the Washington Department of Fish and Wildlife (WDFW), NMFS, and the Service.

2. ***Channel Reconfiguration and Overflow Bench and Spoil Pile Grading***
   Stabilization of the shoreline and construction of a stable natural meander will consist of reconstructing the channel with a bottom width of 30-feet and 3:1 slopes on both sides. Over time, the movement of bedload is expected to reshape the reconstructed channel and existing emergency channel into a single channel. Proposed channel reconstruction will require approximately 3,800 yd^3 of excavation.

   Construction of the proposed overflow bench uses excavated material from the reconstructed channel. The overflow bench will be 6 feet above the constructed channel bottom, 2-3 feet below the adjacent field, and approximately 1 foot above the OHWM. The bench will transition to the adjacent field at a 3:1 slope and will vary in width from 0-84 feet with a slight slope to the stream. Construction of the bankfull bench will require approximately 3,300 yd^3 fill material from the channel excavation.

   Additionally, approximately 3,000 yd^3 of existing spoil piles from previously completed, unpermitted work will be spread on the right bank of the Teanaway river within the floodplain area. No remnant channels will be filled.

3. ***Installation of Rock Vanes and Large Woody Debris (LWD)***
   Four rock vane structures, each measuring 80 feet in length, will be constructed along the left bank. The structures will be spaced 150 feet apart and extend into the stream channel at a 25 degree angle from the overflow bench. Construction of the rock vanes will

require 1,876 yd^3 of rock. Approximately 110 yd^3 will be salvaged from previous work at the site while the remainder will be obtained from areas off site. Approximately 4,000 square feet of rock will be exposed above the channel bottom. Only 2,000 square feet will be exposed above ordinary high water. Approximately 80-90% of the vanes will be embedded into the channel. The voids in the rock vanes will be filled with excess gravels. All backfill will be composed of native materials. The rock vanes will contain a small wood structure consisting of two harvested and limbed trees with the attached root wad boles. The trees will be angled and buried inside the vanes except for the rootwad boles located on the downstream side of the vane.

Large wood structures will be located upstream and downstream of the vanes and consist of five harvested and limbed trees with the attached root wad boles. The large wood structures will consist of three rootwad bole members and one anchor log member. Each rootwad bole member will be pinned to each anchor log member, and the composite structure will be anchored by placing six 42-inch diameter ballast boulders on top. Additional anchorage is achieved by burial of most of the composite structure using large native channel bottom material as fill. Scour pools associated with the large wood structures auto-generate during flooding, nonetheless, excavations immediately downstream of each root wad bole will be carried out to initiate their formation. Fill (from onsite; native material excavated from the channel) will be put around the vanes and log structures to create the new primary channel.

4. ***Planting***

Vegetation will be planted as the vanes and log structures are installed. Willow (*Salix* spp.) cuttings and other suitable riparian vegetation will be planted between the wood structures, vanes and throughout the overflow bench. The vegetation that will be planted in the wetted perimeter will be planted during construction using the heavy equipment on site (Aug/Sept) in order to get the roots down to the water and increase the survival rate. The entire riparian planting area, at or above the elevation of the overflow bench, will be seeded with the grasses. Upland vegetation will be planted during a more suitable time to ensure survival following construction (November or February). Trees/shrubs will be intermixed within designated areas at 600 stems per acre.

The native plant species selected for installation will include those that are common to the riparian zone in this area, such as black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), willow, and red osier dogwood (*Cornus sericea*). Ponderosa pine (*Pinus ponderosa*) and upland shrub species will also be planted. This approach will encourage the establishment of a riparian vegetation community, which is currently lacking from this property, to assist in stabilization of the streambank and to improve habitat for fish and wildlife. Riparian vegetation helps to stabilize streambanks through root cohesion and by preventing surface soil erosion by intercepting precipitation. Live stakes incorporated into LWD structures and other structural components will also assist in further stabilizing these elements.

These Project elements are used throughout the remainder of this biological opinion to describe and evaluate the likely consequences of the Project for the bull trout and its critical habitat.

1.1 Conservation Measures

When used in the context of the Act, conservation measures are actions that are included by the Federal agency as an integral part of the proposed action. Because conservation measures are pledged in the Project description by the action agency, their implementation is required under the terms of the consultation (USDI and USDC 1998, page 4-19).

Construction will occur during the fall (August 15 - October 15) when flows in the Teanaway River will likely be the lowest. This approach follows the work window recommendation by WDFW. Although it is expected that the cofferdam will prevent turbid water created in the work area from discharging into the river, surface water quality will be monitored during construction to ensure compliance with the Department of Ecology's mixing zone requirements (WAC173-201A-400). Since the Teanaway River in this reach will likely flow at an average of less than 150-250 cubic feet per second (cfs) during the Project's construction window (September – October), the mixing zone specified by Ecology is 300 feet downstream and 100 feet upstream from the project site. Turbidity must not exceed 5 NTU above background outside of this mixing zone (USGS 2010, WAC 173-201A-400). Trained staff will collect measures of turbidity prior to construction and then compare results to periodically collected samples taken 300 feet downstream of the northernmost extent of the Project site during construction. If allowable limits are exceeded, the engineer will be notified to take corrective action (e.g., stop work and augment cofferdam with additional gravel bags).

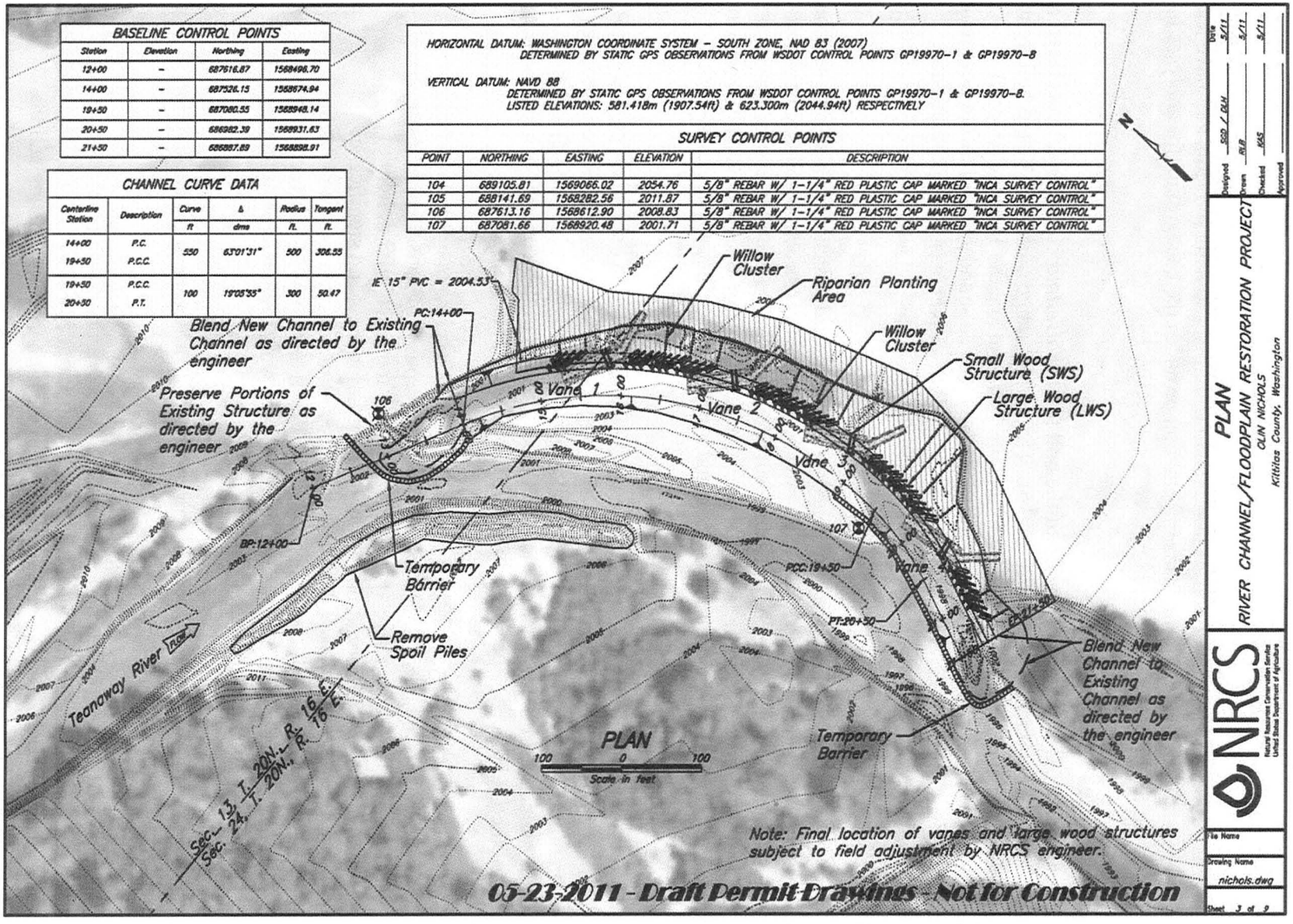
A spill prevention, control, and countermeasures (SPCC) plan will be implemented to guard against the release of any harmful pollutant or product. No heavy equipment will be staged or fueled within 150 feet of the stream. No heavy equipment will be operated from within the active stream channel.

1.2 Definition of the Action Area

The action area is defined as all areas to be affected directly or indirectly by the Federal action, including interrelated and interdependent actions, and not merely the immediate area involved in the action (50 C.F.R. 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment. Subsequent analyses of the environmental baseline, effects of the action, cumulative effects, and levels of incidental take are based upon the action area as determined by the Service.

The proposed Project is located in the Teanaway River Watershed. Within the Teanaway River 5th field watershed, the action area includes a reach that extends roughly 200 feet upstream of the area where construction will occur, to about 600 feet downstream of construction (Figure 1). For this Project we define the upstream boundary of the action area based on the approximate distance that we expect bull trout to detect and respond to noise, vibration and movement associated with construction, and attempt to avoid these disturbances. We define the downstream boundary based on our expectation that suspended sediment and increased turbidity generated by construction and post-construction run-off will settle-out and reach levels that have insignificant impacts to bull trout within about 600 feet of the downstream end of construction. The Project may also influence the dynamics of fluvial geomorphic processes within this action area.

Figure 1. Action area with proposed construction.



2 STATUS OF THE SPECIES FOR BULL TROUT

This section, along with Appendix A, provides information about the bull trout's life history, habitat preferences, geographic distribution, population trends, threats, and conservation needs. This includes description of the effects of past human activities and natural events that have led to the current status of the bull trout. This information provides the background for analyses in later sections of the biological opinion.

2.1 Listing Status and Distribution

The coterminous United States population of the bull trout (*Salvelinus confluentus*) was listed as threatened on November 1, 1999 (64 FR 58910). The current range of the threatened bull trout extends from the Klamath River Basin of south-central Oregon and the Jarbidge River in Nevada, north to various coastal rivers of Washington, to Puget Sound and east throughout major rivers within the Columbia River Basin to the St. Mary-Belly River, east of the Continental Divide in northwestern Montana (Cavender 1978, Bond 1992, Brewin and Brewin 1997, Leary and Allendorf 1997).

Throughout its range, the bull trout is threatened by the combined effects of habitat degradation, fragmentation and alterations associated with: dewatering, road construction and maintenance, mining, and grazing; the blockage of migratory corridors by dams or other diversion structures; poor water quality; incidental angler harvest; entrainment (a process by which aquatic organisms are pulled through a diversion or other device); and introduced non-native species (64 FR 58910).

The bull trout was initially listed as three separate Distinct Population Segments (DPSs)(63 FR 31647, 64 FR 17110). The preamble to the final listing rule for the United States coterminous population of the bull trout discusses the consolidation of these DPSs, plus two other distinct population segments, into one listed taxon, and the application of the jeopardy standard under section 7 of the Endangered Species Act relative to this species (64 FR 58930):

> Although this rule consolidates the five bull trout DPSs into one listed taxon, based on conformance with the DPS policy for purposes of consultation under section 7 of the Act, we intend to retain recognition of each DPS in light of available scientific information relating to their uniqueness and significance. Under this approach, these DPSs will be treated as interim recovery units with respect to application of the jeopardy standard until an approved recovery plan is developed. Formal establishment of bull trout recovery units will occur during the recovery planning process.

Thus, the Service's jeopardy analysis for the proposed Project is done at the scale of the Columbia River interim recovery unit.

On January 9, 2001, the Service proposed to list the Dolly Varden (*Salvelinus malma*) as a threatened species in Washington due to similarity of appearance (66 FR 1628). This proposed listing has not been finalized due to the need to complete higher priority listing actions.

2.2 Current Status and Conservation Needs

A summary of the current status and conservation needs of the bull trout within these units is provided below. A comprehensive discussion of these topics is found in the Service's draft recovery plan for the bull trout (USFWS 2002a; 2004a, b), the Service's Science Team Document (Whitesel et al. 2004), Critical Habitat Listing Rule (USFWS 2005), the Rock Creek Mine Biological Opinion (USFWS 2006), and the 5-year review (USFWS 2008).

The habitat conservation needs of the bull trout are generally expressed as the "four Cs": cold, clean, complex, and connected habitat. Cold stream temperatures, clean water quality that is relatively free of sediment and contaminants, complex channel characteristics (including abundant large wood and undercut banks), and large patches of such habitat that are well connected by unobstructed migratory pathways are all needed to promote conservation of bull trout at multiple scales ranging from the coterminous United States to local populations. The recovery planning process for the bull trout has also identified the following conservation needs for the bull trout: (1) maintain and restore multiple, interconnected populations in diverse habitats across the range of each interim recovery unit; (2) preserve the diversity of life-history strategies; (3) maintain genetic and phenotypic diversity across the range of each interim recovery unit; and (4) establish a positive population trend (USFWS 2002a; 2004a, b).

Central to the survival and recovery of the bull trout is the maintenance of viable core areas (USFWS 2002a, 2004a, b). A core area is defined as a geographic area occupied by one or more local bull trout populations that overlap in their use of rearing, foraging, migratory, and overwintering habitat, and in some cases in their use of spawning habitat. Each of the interim recovery units consists of one or more core areas. About 114 core areas are recognized across the coterminous United States range of the bull trout (USFWS 2002a; 2004a, b).

As noted above, in recognition of available scientific information relating to their uniqueness and significance, five segments of the coterminous United States population of the bull trout are considered essential to the survival and recovery of this species and are identified as interim recovery units: (1) Jarbidge River; (2) Klamath River; (3) Columbia River; (4) Coastal-Puget Sound; and (5) St. Mary-Belly River. Each of these segments is necessary to maintain the bull trout's distribution, as well as its genetic and phenotypic diversity, all of which are important to preserve the species' resilience to changing environmental conditions.

2.3 Jarbidge River

This interim recovery unit currently contains a single core area with six local populations. Less than 500 resident and migratory adult bull trout, representing about 50 to 125 spawners, are estimated to occur within the core area. The current condition of the bull trout in this interim recovery unit is attributed to the effects of livestock grazing, roads, angler harvest, timber harvest, and the introduction of non-native fishes (USFWS 2004a). The draft bull trout recovery plan identifies the following conservation needs for this unit: maintain the current distribution of the bull trout within the core area; maintain stable or increasing trends in abundance of both resident and migratory bull trout in the core area; restore and maintain suitable habitat conditions for all life history stages and forms; and conserve genetic diversity and increase natural opportunities for genetic exchange between resident and migratory forms of the bull trout. An estimated 270 to 1,000 spawning fish per year are needed to provide for the persistence and

viability of the core area and to support both resident and migratory adult bull trout (USFWS 2004a).

2.4 Klamath River

This interim recovery unit currently contains three core areas and 12 local populations. The current abundance, distribution, and range of the bull trout in the Klamath River Basin are greatly reduced from historical levels due to habitat loss and degradation caused by reduced water quality, timber harvest, livestock grazing, water diversions, roads, and the introduction of non-native fishes (USFWS 2002a). Bull trout populations in this unit face a high risk of extirpation (USFWS 2002a). The draft bull trout recovery plan (USFWS 2002a) identifies the following conservation needs for this unit: maintain the current distribution of the bull trout and restore distribution in previously occupied areas; maintain stable or increasing trends in bull trout abundance; restore and maintain suitable habitat conditions for all life history stages and strategies; conserve genetic diversity and provide the opportunity for genetic exchange among appropriate core area populations. Eight to 15 new local populations and an increase in population size from about 3,250 adults currently to 8,250 adults are needed to provide for the persistence and viability of the three core areas (USFWS 2002a).

2.5 Columbia River

This interim recovery unit currently contains about 100 core areas and 500 local populations. The condition of the bull trout within these core areas varies from poor to good, but generally all have been subject to the combined effects of habitat degradation, fragmentation, and alteration associated with one or more of the following activities: dewatering; road construction and maintenance; mining, and grazing; the blockage of migratory corridors by dams or other diversion structures; poor water quality; incidental angler harvest; entrainment into diversion channels; introduced non-native species; and the decline or elimination of salmon populations which provided an important prey base and other essential aquatic ecosystem functions. The draft bull trout recovery plan identifies the following conservation needs for this unit: maintain or expand the current distribution of the bull trout within core areas; maintain stable or increasing trends in bull trout abundance; maintain/restore suitable habitat conditions for all bull trout life history stages and strategies; and conserve genetic diversity and provide opportunities for genetic exchange (USFWS 2002a).

The size and diversity of the Columbia River interim recovery unit make it difficult to determine its current status and the potential unit-wide ramifications of implementing individual projects. The Columbia River Unit occupies all or parts of Washington, Oregon, Idaho and Montana, and contains about 100 discrete or semi-discrete core areas (USFWS 2008). The degree to which demographic performance of core areas is correlated across this vast geography is unknown. Given the large number of factors and threats that influence bull trout populations, it is reasonable to expect different core areas across the Unit to experience different arrays of factors that yield a shifting mosaic of stable, increasing, and declining demographic performance. This mosaic of demographic performance obscures the Unit's actual level of resilience, and at the scale of individual projects, may increase its apparent resilience to persistent localized degradations in habitat quality.

The Service compiled information about core area resilience for its 5-year review of bull trout status, but did not aggregate this information into assessments at the unit-wide scale (USFWS 2008. The core area risk assessment indicates that 76 percent of the core areas in the Columbia River interim recovery unit are in the two highest-risk categories. This risk profile suggests that unit-wide resilience to further habitat degradation may be limited. Population trends for most core areas in the unit are unknown. Distribution of bull trout at the core area scale has not changed since the coterminous listing in 1999, but distribution changes at the scale of local populations have not been comprehensively evaluated. Furthermore, genetic information necessary for identifying core areas that are distinctive elements of intra-unit diversity is being developed, but is not currently available. Overall, the high number of and variability among core areas, difficulty of assessing aggregate risk, lack of key biological information, and the lack of a completed Recovery Plan to inform 7(a)(2) analysis all contribute to uncertainty about the current status of the Unit and the potential Unit-wide consequences of localized project effects.

2.6 Coastal-Puget Sound

Bull trout in the Coastal-Puget Sound interim recovery unit exhibit anadromous, adfluvial, fluvial, and resident life history patterns. The anadromous life history form is unique to this unit. This interim recovery unit currently contains 14 core areas and 67 local populations (USFWS 2004b). Bull trout are distributed throughout most of the large rivers and associated tributary systems within this unit. With limited exceptions, bull trout continue to be present in nearly all major watersheds where they likely occurred historically within this unit. Generally, bull trout distribution has contracted and abundance has declined especially in the southeastern part of the unit. The current condition of the bull trout in this interim recovery unit is attributed to the adverse effects of dams, forest management practices (e.g., timber harvest and associated road building activities), agricultural practices (e.g., diking, water control structures, draining of wetlands, channelization, and the removal of riparian vegetation), livestock grazing, roads, mining, urbanization, angler harvest, and the introduction of non-native species. The draft bull trout recovery plan (USFWS 2004b) identifies the following conservation needs for this unit: maintain or expand the current distribution of bull trout within existing core areas; increase bull trout abundance to about 16,500 adults across all core areas; and maintain or increase connectivity between local populations within each core area.

2.7 St. Mary-Belly River

This interim recovery unit currently contains 6 core areas and 9 local populations (USFWS 2002a). Currently, the bull trout is widely distributed in the St. Mary River drainage and occurs in nearly all of the waters that it inhabited historically. Bull trout are found only in a 1.2-mile reach of the North Fork Belly River within the United States. Redd count surveys of the North Fork Belly River documented an increase from 27 redds in 1995 to 119 redds in 1999. This increase was attributed primarily to protection from angler harvest (USFWS 2002a). The current condition of the bull trout in this interim recovery unit is primarily attributed to the effects of dams, water diversions, roads, mining, and the introduction of non-native fishes (USFWS 2002a). The draft bull trout recovery plan (USFWS 2002a) identifies the following conservation needs for this unit: maintain the current distribution of the bull trout and restore distribution in previously occupied areas; maintain stable or increasing trends in bull trout abundance; restore and maintain suitable habitat conditions for all life history stages and forms; conserve genetic

diversity and provide the opportunity for genetic exchange; and establish good working relations with Canadian interests because local bull trout populations in this unit are comprised mostly of migratory fish, whose habitat is mostly in Canada.

2.8 Life History and Population Dynamics

Like other salmonids from western North America, the bull trout is a well studied fish species. Detailed summaries of available information about the diverse life-history strategies exhibited by bull trout and the resulting variability in population dynamics are available in the Service's draft bull trout recovery plan and in the background information for the 5-year status review of the bull trout. A brief overview of this information is presented in Appendix A.

2.9 Consulted-on Effects

Projects subject to Section 7 consultation under the Act have occurred throughout the range of bull trout. Singly or in aggregate, these projects could affect the species' status. In order to assess the effects of previous actions/projects on bull trout, we incorporate by reference the Service's Biological Opinion for the Rock Creek Mine in Montana prepared by our Region 6 office (USFWS 2006). In the Status of the Species section of that BO, the Service reviewed 137 BOs produced by the Service from the time of listing in June 1998 until August 2003. The Service analyzed 24 different activity types (e.g., grazing, road maintenance, habitat restoration, timber sales, hydropower, etc.). Twenty BOs involved multiple projects, including restorative actions for bull trout.

The geographic scale of projects analyzed in these BOs varied from individual actions (e.g., construction of a bridge or pipeline) within one basin, to multiple-project actions, occurring across several basins. Some large-scale projects affected more than one interim recovery unit. In summary, 124 BOs (91 percent) applied to activities affecting bull trout in the Columbia River population, 12 BOs (9 percent) applied to activities affecting bull trout in the Coastal-Puget Sound population, 7 BOs (5 percent) applied to activities affecting bull trout in the Klamath River population, and 1 BO (less than 1 percent) applied to activities affecting the Jarbidge and St. Mary Belly populations.

Our aggregate analysis of BOs was also stepped-down from the interim recovery unit scale to the core area scale (USFWS 2006). For example, the Rock Creek Mine Biological Opinion included an evaluation of the Clark Fork River basin from the time of listing until August 2003. Of 37 actions that occurred in this river basin during this period, the majority (35) involved habitat disturbance with unquantifiable effects, 16 actions were ongoing, and 21 actions had been completed and effects were no longer occurring. Similarly, the number of actions, type of actions, and a brief description of the action was provided for each river basin where bull trout may have been adversely affected (USFWS 2006).

For each action, the causes of adverse effects were identified, as were the anticipated consequences for spawning streams and/or migratory corridors, if possible (in most cases, these consequences were known). Actions whose effects were "unquantifiable" numbered 55 in migratory corridors and 55 in spawning streams. The Service also attempted to define the duration of anticipated effects (e.g., "short-term effects" varied from hours to several months). Projects likely to result in long-term benefits also were identified.

At the time of preparation of the Rock Creek Mine Biological Opinion, all other BOs within the range of bull trout reached a "no-jeopardy" determination. After reviewing previous BOs, the Service concluded that the continued long-term survival and existence of the bull trout had not been appreciably reduced range-wide (USFWS 2006). The Service's assessment of BOs from the time of listing until August 2003 (137 BOs), confirmed that no actions that had undergone Section 7 consultation during this period, considered either singly or cumulatively, would appreciably reduce the likelihood of survival and recovery of the bull trout or result in the loss of any (sub) populations (USFWS 2006).

Between August 2003 and July 2006, the Service issued 198 additional BOs that included analyses of effects on bull trout (USFWS 2006). These BOs also reached "no-jeopardy" determinations, and the Service concluded that the continued long-term survival and existence of the species had not been appreciably reduced range-wide due to these actions (USFWS 2006). All BOs issued after July 2006 also reached "no-jeopardy" determinations. Since July 2006, a review of the data in our national Tracking and Integrated Logging System (TAILS) reveal this trend has held true to date; no jeopardy opinions have been issued for the bull trout. Also, the Service has developed the Consulted-on Effects Database (COED), an internal online electronic data collection, storage and retrieval system for bull trout. This will provide a powerful tool for assessing the rangewide status of bull trout, and is scheduled for full implementation in the fall of 2011. The COED system is currently being populated with data regarding project effects and associated incidental take from past Federal consultations.

3 ENVIRONMENTAL BASELINE

Regulations implementing the Act (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area. Also included in the environmental baseline are the anticipated impacts of all proposed Federal projects in the action area that have undergone section 7 consultation, and the impacts of State and private actions which are contemporaneous with the consultation in progress. This section analyzes the current condition of the bull trout in the action area, the factors responsible for that condition, and the intended role of the action area in the conservation of the Columbia River interim recovery unit.

Characterizing the environmental baseline for highly mobile species requires a multi-scale analysis that evaluates the condition of all areas used by the affected population. The population of bull trout found in the action area of a project often inhabits a much larger area through the course of its life cycle. For example, bull trout often migrate over 100 km between spawning and overwintering habitat. For bull trout, the Service primarily considers two different spatial scales: (1) the watershed or specific reaches in a watershed affected by the proposed project, and (2) the "core area" scale, which typically incorporates multiple watersheds occupied by separate, but potentially interacting, local populations of bull trout. The watershed or reach scale is used to characterize habitat conditions in the vicinity of the proposed action.

The condition of habitat at both scales is evaluated in terms of seven broad classes of habitat features (pathways), each of which has a related set of specific metrics (indicators) that are rated based on their functional condition. Baseline conditions for each indicator are described on a relative scale of functionality ("properly functioning," "functioning at risk" or "not properly functioning"). This analytical framework is referred to as the Matrix of Pathways and Indicators (MPI) (USFWS 1999). In a similar fashion, the condition of bull trout metapopulations at the core area scale is evaluated in terms of "subpopulation" indicators in the Matrix of Pathways and Indicators (USFWS 1999). The Service uses these hierarchical scales to structure its evaluation of baseline condition as well as its subsequent analysis of project effects and jeopardy.

The action area is part of the Yakima River core area for the bull trout. The Draft Bull Trout Recovery Plan (USFWS 2002b) included all local populations in the Yakima Basin in a single core area. However, based on migratory blockages that limit opportunities for downstream migration and preclude upstream migration under current conditions, the core area is composed of several reproductively isolated population groups. For context, we first discuss the baseline condition of the bull trout within the Yakima core area, followed by a discussion of baseline conditions in the Teanaway River watershed. In the following analysis of baseline conditions, most information for the core area scale is drawn from the *Draft Bull Trout Recovery Plan* (USFWS 2002b) with updates from a variety of other sources. Information for the watershed or reach scale is drawn primarily from the Project BA, the Washington State Forest Practice Habitat Conservation Plan (FPHCP) Biological Opinion (USFWS 2006b), Priest Rapids and Rocky Reach Hydroelectric License Renewal Project Biological Opinions (USFWS 2007, 2008b.)

Habitat information for the basin, watershed, and reach scales is drawn primarily from detailed descriptions in the a limiting habitat factors analysis developed for the Yakima basin (Washington State Conservation Commission [WSCC] 2001), the Yakima subbasin plan (Yakima Basin Fish and Wildlife Planning Board [YBFWPB] 2004), and in the draft Yakima salmon recovery plan (Yakima Basin Fish and Wildlife Recovery Board [YBFWRB] 2005).

3.1 Environmental Baseline for the Yakima Core Area

The Yakima River Basin is located in south central Washington. It consists of two primary sub-basins; the Yakima River sub-basin to the north and the Naches River sub-basin to the south. Combined, these two sub-basins drain an area of about 6,155 square miles (15,900 square kilometers). Along the western portion of the Basin, the glaciated peaks of the Cascade Mountains exceed 8,000 feet. East and south from the Cascade crest, the elevation decreases to the broad valleys and the lowlands of the Columbia Plateau. The lowest elevation in the Basin is 340 feet at the confluence of the Yakima and Columbia Rivers at Richland. Precipitation is highly variable across the Basin, ranging from approximately over 140 inches per year near the crest of the Cascades, to 7 inches per year near the Columbia confluence. Total runoff from the basin averages approximately 3.4 million acre-feet per year, ranging from a low of 1.5 to a high of 5.6 million acre-feet (YBFWPB 2004).

Natural hydrology of the area was historically driven by heavy snowfall from November through March resulting in peak flows derived from snowmelt from May to July. Late fall and winter rain-on-snow events also produced high flows. Historically, the hydrologic cycle in this Basin was characterized by extensive and complex exchange of water between the surface, hyporheic

(shallow groundwater made up of downwelling surface water) and groundwater zones. Under pre-1850s conditions, vast alluvial flood plains were connected to complex webs of braids and channels. These large hydrological buffers spread and diminished peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For salmonids, these side channel complexes increased productivity, carrying capacity, and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity (YBFWPB 2004).

Current hydrology in the Yakima core area is controlled by the Bureau of Reclamation's Yakima Basin Project, and these controlled flows deviate significantly from the natural flow regime. There are five major storage reservoirs in the basin; Keechelus, Kachess, and Cle Elum in the Yakima sub-basin, and Bumping and Rimrock in the Naches sub-basin. None of the dams forming these reservoirs provide upstream fish passage. Total storage capacity of all reservoirs is approximately 1.07 million acre feet; total diversions average over 2.5 million acre feet. Several minor storage dams and many diversion dams are present in the Basin. The construction and operation of this irrigation system has significantly altered the natural seasonal hydrograph of all downstream reaches of the mainstem and some tributaries.

Private ownership totals over 1.2 million acres of the nearly 4 million acres in the Yakima Basin. The single largest landowner is the U.S Government with 1.5 million acres, or 38 percent of the land area. Most of the federal land is within the Okanogan and Wenatchee National Forest. Other large federal land holdings include the U.S. Army Yakima Training Center, a portion of the Department of Energy Hanford Nuclear Reservation, and Bureau of Land Management lands. Other public ownership (state, county, and local governments) total over 400,000 acres. The entire Yakima Basin lies within areas either ceded to the United States by the Yakama Nation or areas reserved for the use of the Yakama Nation. The Yakama Reservation occupies about 40 percent of Yakima County and about 15 percent of the basin (YBFWPB 2004).
Land use above the confluence of the Naches and Yakima rivers is dominated by timber production, grazing, and recreation. The area below the confluence is dominated by intensive irrigated agriculture. Ahtanum Creek is the only major tributary below this confluence known currently to support spawning bull trout. Migratory bull trout have been located as far downstream in the mainstem of the Yakima as Benton City, and are known to use the Mainstem Columbia River as for foraging, migration, and overwintering.

At the time of listing, the Service considered a bull trout "sub-population" to be "a reproductively isolated group of bull trout that spawns within a particular area of a river system." During the recovery planning process, the Service discontinued use of the term "sub-population" in favor of the term "local population" which we define similarly as "a group of bull trout that spawn within a particular stream or portion of a stream system;" a local population is considered to be the smallest group of fish that is known to represent an interacting reproductive unit. Resident and migratory (both fluvial and adfluvial) bull trout are found throughout the Yakima Core Area. Bull trout in the Yakima Core Area are currently distributed in 16 local populations:

1. Mainstem Upper Yakima River (Keechelus Dam to Easton Reach for spawning, with some migration/overwintering in lower Yakima)
2. Ahtanum Creek (North, South, and Middle Forks)

3. American River (Union and Kettle creeks)
4. Bumping River
5. Deep Creek (Bumping Lake)
6. Rattlesnake Creek
7. Crow Creek
8. North Fork Tieton River (Rimrock Lake)
9. South Fork Tieton River (Rimrock Lake)
10. Indian Creek (Rimrock Lake)
11. Teanaway River and tributaries (North Fork Teanaway)
12. Box Canyon Creek (Kachess Lake)
13. Upper Kachess River - including Mineral Creek (Kachess Lake)
14. Gold Creek (Keechelus Lake)
15. Cle Elum River (including Cooper River and Cooper Lake)
16. Waptus River and Waptus Lake

Taneum Creek, in the upper Yakima River, is a location where bull trout reintroduction is expected, potentially creating the seventeenth local population in the core area (see the draft Bull Trout Recovery Plan for more detailed information).

3.1.1 *Conservation Role of the Yakima Core Area*

The Yakima core area may play a central role in the conservation of the Columbia River interim recovery unit of the bull trout. Not all of the information necessary to definitively determine the appropriate conservation role of this core area is available, but a reasonable working hypothesis can be deduced from what is known. Geographically, this core area is the largest in the Columbia River interim recovery unit in Washington State, and among the largest in the entire unit. Simply by virtue of its large size, the Yakima core area plays an important role in maintaining the spatial distribution of bull trout within the unit.

Not only is the Yakima core area large in size, it is also located at a major intersection in the Columbia basin, where the upper Columbia and Snake River evolutionary groups meet (see Spruell et al. 2003). The Yakima core area may be a "mixing zone" between these areas in terms of demographic and genetic exchange (USFS 2004, p. 6; Ardren at al 2010, p. 26). This raises the likelihood that the Yakima core area may have a distinctive genetic background, containing elements from both of these adjacent lineages. If the Yakima core area proves to be a repository of rare alleles or unusual combinations of loci from different lineages, this core area could be essential for maintaining genetic diversity within the unit.

From a demographic perspective, the Yakima River was historically among the most productive sub-basins for anadromous salmon in the Columbia basin. Before 1850, an estimated 500,000 to 900,000 salmon and steelhead returned annually to the Yakima basin (YSF&WPB 2004). Since that time, sockeye, summer Chinook, and coho salmon have been extirpated, coho have been reintroduced, and in the last 10 years, the largest total runs including all species have been less than 30,000 fish (YSF&WPB 2004). No estimates of historic bull trout abundance are available, but high productivity of anadromous salmon and the presence of several natural lakes that could support adfluvial life-history strategies suggest that migratory bull trout populations historically were also large and prolific. The Yakima core area had the biological potential to serve as a

source population exporting migratory emigrants to smaller and less stable core areas in both the upper Columbia and Snake River basins. Movements of this scale are within the range of migration distances documented by recent telemetry studies (e.g., BioAnalysts 2004). Providing gene flow between the major evolutionary lineages and demographic support to less productive core areas in the vicinity may have been the historic roles of the Yakima core area in the unit. This hypothesized reference condition could suggest the appropriate conservation objective for the Yakima core area in the recovery of the Columbia River interim recovery unit.

If these hypothesized roles of the Yakima core area are correct, extirpation or functional extirpation of bull trout from this core area could have negative consequences for the distribution, numbers, and reproduction of the Columbia River interim recovery unit. A large gap would be present at a central location in the unit. This gap would exceed the distance that bull trout typically move during migration. Natural recolonization of the Yakima core area would require exceptional movements by fish from surrounding core areas, making management intervention (reintroduction) the only option for restoring bull trout to the Yakima with a reasonable likelihood of success in the foreseeable future. If native Yakima bull trout have unique genotypes, extirpation would reduce genetic diversity. If native Yakima bull trout are also locally adapted, reintroduced fish may not be as productive as the native population, or achieving successful reintroduction may be challenging. Genetic exchange between the upper Columbia and Snake lineages would be curtailed, and would only occur through management intervention, such as translocating spawners. Core areas within migratory distance of the Yakima that may historically have benefited from demographic support from this population would now be more isolated and deprived of demographic and genetic inputs, likely diminishing the probability of persistence of these core areas. All of these outcomes are contrary to the recovery goals and objectives in the Service's draft recovery plan.

The current status of a bull trout at the core-area scale can be summarized based on the seven Pathways in the MPI: 1) population characteristics, 2) water quality, 3) habitat access or connectivity, 4) habitat elements, 5) channel condition and dynamics, 6) flow/hydrology, and 7) watershed condition. Each of these pathways is described specifically for the Yakima core area in the following sub-sections. We conclude our summary assessment of baseline conditions by reviewing both positive and negative factors affecting the quality and quantity of bull trout habitat in the Yakima core area, and by listing the most potent threats to the persistence of bull trout in the core area.

3.1.2 *Population characteristics*

Historically, bull trout occurred throughout the Yakima River basin. Although a large number of bull trout local populations are still widely scattered across the basin, currently they are fragmented into isolated local units. Among the 16 local populations, most are isolated above impassible dams with limited, one-way, downstream export of individuals, or they are connected to only one or two other local populations. Survival rates of bull trout passing downstream through these dams are unknown, but high rates of mortality have been documented for other species. Historic patterns of seasonal migration, as well as demographic and genetic exchange among local populations, have been severely curtailed by barriers resulting from human activities during the last century.

The Yakima Core Area includes long sections of FMO habitat in the mainstem Yakima River, including connections to the Columbia River. Historic conditions provided access to many large wetland and lake habitat features that bull trout could choose to use as FMO habitat. Historically, bull trout could have migrated upstream or downstream from these lakes to spawning habitat. Currently, passage barriers, including five major BOR irrigation reservoirs, limit access to both spawning and FMO habitat.

3.1.3 *Number and Distribution of Local Populations*

Because of anthropogenic changes and the lack of migratory connectivity between most local populations in the Yakima Basin, the approximately 16 existing local populations currently function as, at most, nine reproductively isolated populations.

In the Tieton drainage above the Tieton Dam, local populations of bull trout are found in the South Fork Tieton River (including Bear Creek), North Fork Tieton River, and Indian Creek. These local populations most likely originated from native fluvial bull trout in the Tieton River. Construction of the Tieton Dam in 1925 forced bull trout in these local populations to adopt an adfluvial life-history pattern. In the South Fork, juvenile bull trout have been observed in several tributaries including Short and Dirty, Grey, Spruce, and Corral Creeks. In the North Fork, information about the bull trout local population is very limited. Catch records for Clear Lake on the North Fork Tieton documented bull trout presence in the 1950's. In 1993, U.S. Forest Service staff reported capturing one 75 to 100 millimeter (3 to 4 inch) bull trout from a minnow trap in Clear Lake. In addition, biologists from Central Washington University observed an adult bull trout in the upper North Fork Tieton River in 1996. Interagency surveys located both adult migratory bull trout and one redd in the North Fork Tieton River in 2004 and over 37 redds in 2007.

Below the Tieton Dam, bull trout also have been found in the Tieton River. Whether these bull trout represent a self-sustaining local population or are primarily fish that passed through the dam and cannot return upstream is unclear. These fish emigrate to other local populations (e.g., Rattlesnake Creek, American River) to spawn and have been shown to migrate into other areas (Mizell and Anderson 2006; WDFW 2010).

Within the Naches system, other bull trout local populations have been identified in Rattlesnake Creek (including Little Wildcat Creek), American River (including Union and Kettle creeks), and in the Little Naches River in Crow Creek. Bull trout greater than 500 mm (20 inches) in length have been observed spawning in the American River (WDFW 1998), indicating these are migratory individuals.

In the Bumping River, adfluvial bull trout spawn in Deep Creek and rear and mature in Bumping Lake. The local population in Deep Creek probably originated from a native adfluvial life-history form that used the natural lake which was enlarged by dam construction in 1910. Construction of the dam enlarged the natural lake and forced any fluvial bull trout to adopt an adfluvial life history. While Deep Creek is the only identified local population above Bumping Lake, the U.S. Forest Service reported a single redd with three bull trout in the upper Bumping River in 1994. A bull trout redd was seen in the Bumping River during a U.S. Forest Service snorkel survey in September 2003 and juveniles were seen in another snorkel survey in

September 2002. Bull trout also have been found in the Bumping River (below Bumping Lake). Like the bull trout found below Rimrock Lake, the life history and likely spawning locations of these individuals is unknown.

Shifting to the Yakima River sub-basin, the Teanaway River is the first major tributary above the confluence with the Naches River that supports bull trout. The bull trout local population in the Teanaway River is found primarily in the North Fork Teanaway River and in DeRoux Creek. Limited spawning occurs, and most recently two redds were observed by the Service in 2005 (in the North Fork Teanaway River just upstream of DeRoux Creek). Adult and juvenile sized bull trout have also been observed in Jungle and Jack Creeks. Although habitat appears to be suitable for bull trout in the West and Middle Forks of the Teanaway River, no bull trout have been found in these streams. Bull trout in the North Fork Teanaway River are likely a mix of both small resident forms and larger fluvial forms.

In the Kachess River, bull trout local populations above Kachess Dam probably originated from a native adfluvial life-history form, which was present in the existing lake before the construction of the dam in 1905. Local populations identified by the Middle Columbia Bull Trout Recovery Team in this area include Box Canyon Creek and the upper Kachess River. However, some spawning may occur in Mineral Creek when adequate flows are available.

Similar to Kachess Lake, bull trout in Keechelus Lake most likely originated from a native adfluvial life-history form which was present before the construction of the dam and irrigation reservoir in 1914 (which modified the natural lake). Spawning by this local population currently occurs only in Gold Creek. Anecdotal reports indicate that bull trout may have been present in Rocky Run Creek in the early 1980's. Surveys following the protocol to detect bull trout developed by the Western Division of the American Fisheries Society, in cooperation with the Service were conducted in 2001. No bull trout were detected. In 2005, a bull trout was located in Cold Creek, below the barrier culvert.

The Middle Columbia Bull Trout Recovery Team has identified two local populations above Cle Elum Dam; one using Cle Elum mainstem and its tributaries and the other associated with Waptus Lake and River system. These populations may be separated due to distance and geologic landform and/or thermal barriers. A waterfall located on the lower Waptus River between Waptus and Cle Elum lakes may act as a barrier to bull trout migration between the two systems. Additional surveys are needed to determine if additional local populations exist in the Waptus River system. Similar to other areas within the Yakima Core Area, these bull trout most likely originated from a native adfluvial life-history form which was present before the construction of Cle Elum dam in 1931. Construction of the Cle Elum Dam enlarged the natural lake and forced any fluvial bull trout present to adopt an adfluvial life-history pattern. Catch records collected from anglers indicate that bull trout were present in Waptus Lake in the 1940s and early 1950s. Washington Department of Fish and Wildlife (WDFW) biologists confirmed the continued presence of bull trout in Waptus Lake by capturing a single juvenile fish in a gill net in 1996 and a large adult bull trout in 1997.

Radio-telemetry studies conducted outside the Yakima Core Area have shown that bull trout tagged in the mainstem Columbia River move long distances into tributaries to spawn. Thus, it is possible that the bull trout in the Yakima Core Area could migrate to both the lower portion of the Yakima River and the Columbia River, especially to use these areas as overwintering habitat. Telemetry studies in the Yakima basin have found bull trout tagged in the Tieton River, Naches River, and Bumping River overwintering in sections of the mainstem lower/middle Naches and in the Yakima River mainstem down to Ahtanum Creek (Mizell and Anderson 2006). Evidence of bull trout use of the lower Yakima River mainstem is more anecdotal. One bull trout was caught by a WDFW biologist doing surveys near Toppenish in 2003. Another bull trout was tagged with a telemetry transmitter at Rosa Dam, just upstream of the Naches River confluence in 2004. Bull trout have also been observed in the mainstem Columbia River both upstream and downstream of the Priest Rapids Dam and sub-adults have been observed within the fish ladders at both Wanapum and Priest Rapids Dam (USFWS 2007). The Yakima River core area is the most likely source of these individuals.

3.1.4 *Adult Abundance*

Abundance of bull trout in the Yakima Core Area has been tracked primarily through redd surveys conducted on index reaches in spawning areas. Redd surveys are commonly used as an index of local abundance, with the accuracy of this index dependent on rigorous standardization of survey procedures (Dunham et al. 2001). Comparable data from redd surveys for most of the local populations in the Yakima core area are only available between 1999 and 2009. During this period, redd counts have been variable. The number of redds in the Yakima Core Area ranges from 793 in 2009 to 457 in 2005 (Table 1). Since 1999, the annual average number of redds in the Yakima Core area is 572 redds. Fisheries biologists familiar with the Yakima core area think that the number of redds in the Yakima core area is low relative to the amount of habitat available. For this summary, we do not expand the redd count index to estimate number of adult bull trout; instead we make comparisons based on the index.

At the time of listing, bull trout populations were considered at risk of extirpation from naturally occurring events if they were (1) unlikely to be reestablished by individuals from another sub-population (i.e., they are functionally or geographically isolated from other sub-populations), (2) limited to a single spawning area (i.e., spatially restricted), and either (3) characterized by low individual or spawner numbers or (4) primarily of a single life-history form (63 FR 31649). All local populations of bull trout in the Yakima Basin meet one or more of the four factors listed above that increases risk of extirpation. At the time of listing, only the Rimrock Lake sub-population (i.e., Indian Creek and South Fork Tieton River local populations) of bull trout was considered stable; the remaining sub-populations within the Basin were classified as depressed and declining (63 FR 31647). Population status for the Naches River bull trout sub-population was classified as unknown. With the exceptions of Rimrock Lake and the Naches River, the remaining sub-populations were considered to be at risk of extirpation. All local populations in the Yakima Core Area, including the two largest populations (South Fork of the Tieton River and Indian Creek), have effective population sizes which are small enough to categorize as being at high risk of deleterious genetic effects associated with small populations over the medium and long-term. Redd counts are so low for Ahtanum Creek, and for all bull trout populations in the upper Yakima arm (especially the Teanaway), that they are at high risk of extirpation in the short-term. See Appendix A for more information on small population effects.

Table 1. Redd counts for bull trout populations in the Yakima Basin, 1999–2009.

	Year											
Location	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg
Ahtanum Creek												
N.F. Ahtanum Cr.	7	11	20	17	12	8	6	7	8	1	3	9
M.F. Ahtanum Cr.	0	10	1	6	8	11	5	6	5	3	9	6
S.F. Ahtanum Cr.		5	14	13	7	5	3	4	5	3	6	7
Naches River												
Rattlesnake Cr.	44	45	57	69	54	32	15	40	13	37	36	40
American R.	30	44	36	27	30	40	35	55	31	22	39	35
Crow Cr.	19	26	6	9	9	6	4	8	8	2	5	11
Rimrock Lake (isolated by dam)												
S.F. Tieton R.	161	144	158	141	178	178	205	189	152	266	259	185
Indian Cr.	205	226	117	100	101	50	91	106	58	130	200	126
N.F. Tieton (above Clear Lk)						1		1	37	28	15	16
Bumping Lake (isolated by dam)												
Deep Cr.	107	147	51	120	57	97	73	95	46	126	98	92
Yakima River												
N.F. Teanaway R.							2	1	0	0	1	1
Kachess Lake (isolated by dam)												
Box Canyon	17	10	14	15	8	19	8	8	2	8	21	12
Kachess River		15	14	0	16	8	3	0	22	2	2	8
Keechelus Lake (isolated by dam)												
Gold Cr	40	19	15	31	9	20	7	8	6	40	29	20
Cle Elum & Waptus watershed (isolated by dam)												
	0	0	0	0			0	0	0	0	0	0
Grand Total Redds	630	702	503	548	489	475	457	528	477	687	793	572

3.1.4 *Population Growth and Survival (productivity)*

Because estimates of total population size are rarely available, the productivity or population growth rate for bull trout is usually estimated from temporal trends in indices of abundance at a particular life stage, such as redd counts being used to estimate adult abundance. The direction and magnitude of a trend in the index can be used as a surrogate for the growth rate of the entire population. For a population to contribute to recovery, its growth rate must indicate that the population is stable or increasing for a period of time.

Eleven years of consistent data have been collected in the same stream reaches among all local populations in the Yakima Core Area. This relatively short time-series in combination with high interannual variation makes detection of trends in productivity difficult. Overall, the population trend for the Yakima Core area since 1999 is unstable, possibly reflecting uncorrelated temporal variation among the isolated local populations.

In general, a positive relationship exists between heterozygosity and productivity of fish populations (e.g., Allendorf and Leary 1986). The two genetic analyses that have been conducted on bull trout in the Yakima core area yielded divergent results regarding heterozygosity, with one study finding low levels of expected heterozygosity (Reiss 2003) and the other finding generally high levels (Hawkins and Von Bargen 2006). These differences may reflect different methods and scales of analysis. Given the small size of several local populations and corresponding high potential for levels of inbreeding that reduce heterozygosity, it is likely that inbreeding is contributing to some reductions in productivity in small, isolated, local populations, such as those in the upper Yakima sub-basin.

A potentially positive aspect of reservoir development in the Yakima core area is an increase in the area of lake habitat available for foraging and overwinter residence for bull trout. Stocking of some prey species in these lakes, such as kokanee, may have contributed to increased foraging opportunities and increased growth rates by adult bull trout using these lakes. Based on redd counts, these factors that have the potential to increase growth rate do not increase productivity sufficiently to counteract the other aspects of reservoir operations that reduce productivity.

3.1.5 *Summary of Population Characteristics*

Historically, the bull trout occurred throughout the Yakima River Basin. Now populations are fragmented and isolated, and most are located above impassable BOR reservoirs, and therefore do not have access to most of their historic habitat. The Service has developed a methodology for risk assessment of bull trout core areas for use in section 7 consultation (USFWS 2006b, 2007; see Appendix C). This method integrates the condition of all MPI population attributes pathways and indicators and includes consideration of the total number of local populations in the core area. Applying this approach to the Yakima core area we find that it is not properly functioning due to a high likelihood of losing genetic function due to the lack of connectivity between populations and low population numbers. This finding is consistent with the findings of the conservation status assessment conducted as part of the bull trout 5-year review. Using a modified version of the Natural Heritage Program's ranking model, this effort found that the Yakima core area is at "High Risk"; meaning that extremely limited and/or rapidly declining numbers, range, and/or habitat, is making the bull trout in this core area highly vulnerable to extirpation (USFWS 2008, pgs. 29-30).

3.1.6 *Water Quality*

Throughout the irrigation season, the lower Yakima River (downstream from Granger, RM 82) receives large volumes of warm, sediment- and pollutant-laden water from irrigation effluents (Johnson et al. 1986). Diminished stream flows in the Lower Yakima and Naches rivers during the irrigation season, combined with high air temperatures, degraded riparian vegetation, and floodplain development, contribute to extended river reaches with water temperatures that exceed the physiological tolerances of native salmonids (Yakima Basin Fish and Wildlife Recovery Board [YBFWRB] 2005). These conditions are well tolerated by native and non-native predatory fish and serve to increase their foraging efficiency. Additionally, poor water quality conditions in the Lower Yakima River can lead to increased mortality rates in native anadromous smolts and bull trout from water-borne pathogens. High water temperatures persist in the lower Yakima River throughout the irrigation season (YBFWRB 2005).

Water quality conditions throughout the Yakima subbasin are severely impaired along many reaches of the Yakima River and its tributaries largely because of flow regulation, irrigated agriculture, and general floodplain development (YBFWRB 2005) . The Washington State Department of Ecology (WDOE) has placed 72 watercourse segments throughout the Yakima Basin on the most recent 303(d) list (1998) of threatened and impaired waterbodies (WDOE 1998). Primary impairments leading to these listings included increased temperatures, high agricultural pollutant concentrations (e.g., 4,4'-DDE, DDT, dieldrin, 4,4'-DDD, chlorpyrifos, endosulfan, and PCB), dissolved oxygen deficits, and a host of other water quality constituents (e.g., arsenic, mercury, silver, fecal coliform, pH, ammonia, chlorine, turbidity, and phosphorous) that are generally detrimental to fish health and persistence (Johnson et al. 1986).

Bull trout require cold stream temperatures for successful spawning. Throughout the Yakima Basin, over 45 streams have been listed on the 303(d) list of impaired waterbodies due to elevated temperatures. These waterbodies include most of the streams inhabited by local populations of bull trout. Craig (1997) found that streams in the Yakima River basin with more than 20 redds had a 7-day summer mean temperature below 12 °C, and no single day with a temperature > 14.8 °C.

Accelerated sedimentation impairs the growth, health and survival of salmonids (Newcombe and Jensen 1996, Suttle et al. 2004). Approximately 90 percent of the turbidity and suspended sediment in the Yakima River mainstem below Easton Dam are human-produced, and therefore remediable (Creech and Joy 2002). Operation and maintenance activities of the Bureau of Reclamation's Yakima Project have altered the timing, volume, and magnitude of sediment movement in the river through modification of the magnitude and timing of river flows. Irrigation drain maintenance, including dredging and flushing, has also contributed sediment and associated pollutants to the Yakima River system. Based on data collected during the 1995 irrigation season, Joy and Patterson (1997) found that Moxee Drain contributed 35 tons per day of sediment to the lower Yakima River in the latter part of the irrigation season. For comparison, the Naches River (largely unregulated above the Tieton River confluence) contributed only 27 tons per day during this same period, even though average discharge in the river was 14 times

greater than in the drain. Also during this same period, other gauged drains (Spring, Snipes, Sulphur, and Granger creeks) produced an average contribution of 116 tons of sediment per day to the lower Yakima River.

Significant total suspended sediment reductions have been realized since the 1997 assessment as a result of a water quality improvement program implemented by the Roza and Sunnyside Divisions. The sediment input from the Granger and Sulphur Creek drains has been reduced by more than 95 percent (Stanford et al. 2002). This progress is encouraging, but other drains and tributaries continue to contribute large amounts of agriculturally-derived fine sediments to the Yakima River and its tributaries. Although not included on the published Washington State 303(d) list for 1998, Creech and Joy (2002) found that the mainstem Yakima River between Lake Easton and Cle Elum, and from Ellensburg to the Naches River exceeded the state water standards for turbidity. Both of these reaches also contained high levels of suspended sediments (Creech and Joy 2002).

In addition to the direct negative effects of accelerated sedimentation, both turbidity and sediments provide a surface that can absorb or adsorb pollutants. In Yakima basin streams, most of the pesticide t-DDT (total DDT; i.e. the sum of DDT, DDE, and DDD concentrations) is transported by suspended sediment (Joy and Patterson 1997, Creech and Joy 2002). Joy (2002) determined that turbidity and suspended sediments persist for sufficient duration to cause harm to salmonids in the upper Yakima River mainstem.

Sedimentation can also contribute to reductions in invertebrate abundance and diversity, which reduces prey availability for bull trout. The lower Yakima contained noticeably lower numbers of mayflies, caddisflies, and stoneflies than the upper Yakima and no stonefly larvae were found in the mainstem Yakima River (Cuffney et al. 1997 in Snyder and Stanford 2001).

Ebbert and Embrey (2001) found a total of 25 pesticide compounds at 34 sites (including both surface and groundwater) across the Yakima basin, with the highest pesticide detection frequencies and concentrations occurring during the irrigation season. Within the basin, several studies have documented pesticide levels that exceed Environmental Protection Agency or WDFW guidelines to protect wildlife populations from chronic carcinogenic risk, and other investigations have documented the presence of physical abnormalities on fish collected from agricultural drains and the lower Yakima River (Johnson et al. 1986, Cuffney et al. 1997, Morace et al. 1999). Morace et al. (1999) found that the biological impacts of agriculture were manifested by a decrease in the abundance and diversity of native species of fish and invertebrates and a shift in algal communities to high abundances of species indicative of eutrophic conditions. There was also an increase in the abundance and number of non-native fish species that are largely tolerant of nutrient-rich conditions (Morace et al. 1999). Mainstem Yakima River locations downstream from the City of Yakima exhibited the severe impairment of fish communities that is typically associated with high levels of pesticides in fish tissues (Morace et al. 1999). Endosulfan (an organochlorine pesticide), chlorpyrifos and malathion (organophosphate pesticides), dieldrin (a cyclodiene insecticide), Atrazine (a restricted-use herbicide), and acrolein (an herbicide) are all known to have harmful effects to fish, and all of these have been detected in Yakima basin waterbodies at levels exceeding 303(d) criteria.

High concentrations of DDT (and its degradates DDE and DDD) have been detected in fish from the Basin; these concentrations are the highest reported in the United States (Rinella et al. 1992; 1993; USGS 2002). Reported levels of *t*-DDT (total DDT) have ranged from undetectable to over 3000 *u*g/kg in fish tissue from the Yakima River (Johnson et al. 1988). The national standard for fish tissue is 1000 *u*g/kg (USGS 2002). Effects of these contaminants on fish include abnormal behavior (leading to increased predation), increased egg and fry mortality, possible carcinogenic effects, and teratogenic impacts (Extoxnet 1996, Centers for Disease Control 2002). DDT (primarily in the form of *p,p'*-DDE) has been reported throughout the Yakima River (WDOE 1998, Ebbert and Embrey 2001). Overall, DDE was detected in over 50 percent of the samples tested. The concentrations reported ranged from a minimum of six times the EPA chronic-toxicity guideline to as much as nine times the permitted levels (Ebbert and Embrey 2001).

DDT, DDE, and DDD are released back into the water column every time a pulse of water is sent through the system because these compounds are stored in or attached to sediments. Such pulses are typical due to operations of the storage reservoirs in the Basin. Because: (1) bull trout may be present in the lower Yakima at any time; (2) the lower Yakima River is used as a migration/dispersal corridor and for foraging and over wintering by bull trout; and (3) female fish likely contain developing eggs at the time of migration through the lower Yakima River, we conclude that it is reasonably certain that negative impacts from these chemicals to both adult and larval bull trout have, and continue to, occur from BOR Project activities.

Manipulations of the flow regime in the Basin also indirectly affect dissolved oxygen (DO) concentrations. Many waterbodies in the Basin are on the 303(d) list for low DO. Because salmonids are known to avoid areas with low DO and the lower Yakima River is a migration/dispersal corridor for bull trout, low DO levels likely trigger some degree of avoidance behavior in bull trout that attempt to migrate upstream through these reaches. This influences the distribution, reproduction, numbers, and (in the long-term) decreases the likelihood of persistence of affected bull trout populations.

Contaminants, other than pesticides, also have negative impacts on bull trout. Effects of selenium on fish include gross embryo deformities, growth inhibition, depressed immune response, mass wasting, changes in blood parameters and tissue structure, edema, reduced activity and feeding, reduced survival, and mortality (Hamilton and Wiedemeyer 1990). Much of the upper sub-basins (Cle Elum, Upper Naches, Teanaway, and Tieton) contain naturally occurring selenium, with dairy farms that use selenium-supplemented feed and mining operations adding to the total load (Fuhrer et al. 1987). Higher levels of cadmium, mercury, as well as selenium were found in fish tissues from the lower mainstem of the Yakima River than from the upper sub-basins. There is a statewide fish consumption advisory for children and women and childbearing age due to mercury accumulation in fishes.

In addition to the presence of chemical contaminants, other aspects of water chemistry such as pH are degraded in the Yakima Basin. Eleven percent of the 856 pH measurements from 143 sites sampled in the Basin during the 1986 to 1991 water years did not meet State water quality criteria (WDOE 1998, 2002). Ninety-seven percent of these sites had pH values greater than 8.5, outside of the range normally experienced by the aquatic community (6.5-8.5) (WDOE 1998).

Values outside of the normal range for aquatic life may seriously depress the food base for bull trout. Elevated pH may also delay pesticide decomposition, alter nutrient uptake, and synergistically interact with pesticide and heavy metals to weaken and kill salmonids (Kentucky Water Watch 2004, McKie and Johnson 2004).

Reductions in riparian areas in much of the Basin (up to 50 percent in some areas) have reduced the ability of these areas to filter excess nutrients running off of adjacent agricultural and residential areas. Excessive nitrogen (in the forms of ammonia-N) levels have been reported for Crystal Creek, Selah Ditch, upper mainstem Yakima River, Granger Drain, and lower mainstem Yakima River (WDOE 1998).

3.1.7 *Habitat Access or Connectivity*

Connectivity among patches of suitable habitat is another essential conservation need of bull trout. Passage impediments, however, challenge native salmonids across the Yakima subbasin. Access to upstream tributary habitats can be blocked by constructed barriers such as road or pipeline crossings and diversion dams, or by depleted stream flow below diversions (YBFWRB 2005). At some diversions with fish ladders (Roza, Sunnyside, and Prosser dams), seasonal operations at can hinder adult upstream movement during critical migration periods, or completely block access when upstream storage is predicted to be insufficient (Easton Dam). Furthermore, hydropower wasteways such as Roza Power Plant Wasteway, and irrigation drainage features such as Sulphur Creek Wasteway, and Moxee and Granger Drains, which are connected to the Yakima River and its tributaries, discharge false attraction flows that can entrain or confuse migrating fish. Exposure to adverse water quality constituents for fish entrained into these watercourses might significantly decrease their chances of spawning successfully later.

Population genetic studies indicate little gene flow among most local populations of bull trout in the Yakima core area. The genetic structure of twelve spawning populations of bull trout within the Yakima core area has been examined in two studies; one using six polymorphic microsatellite loci (Reiss 2003) and a second using sixteen loci (Hawkins and Von Bargen 2006). Both studies found high variability among populations (e.g., FST = 0.217; Reiss 2003), except among fluvial populations that are not separated by migration barriers. In addition, one population from Rimrock reservoir had similar gene frequencies, possibly reflecting historical connectivity with the fluvial populations (Reiss 2003). In the two reservoirs that contained more than one population, the local population in each spawning stream was genetically distinct.

Telemetry studies of fluvial and resident bull trout also have provided insights about connectivity among populations, population movement patterns, habitat preferences, and over-wintering areas (Mizell and Anderson 2006). The main populations of the Naches River [Tieton (Clear Creek, Indian Creek, S.F. Tieton), Rattlesnake Creek, Bumping River, Crow Creek, American River, Kettle Creek and Union Creek] exhibit nearly identical over wintering behavior in the mainstem Naches River, but timing varies significantly among populations (Mizell and Anderson 2006). Over wintering occurs in several deep pools where the populations intermingle over the winter months, then separate-out for spawning. Across local populations, spawning site fidelity was found to be at or near 100%, supporting the results of genetic analyses. The Ahtanum population was found to be isolated or semi-isolated from the remainder of the Yakima Basin, and the

populations in each of the three forks of the Ahtanum are very nearly isolated from each other (Mizell and Anderson 2006). Bull trout in the Naches River move upwards in the main stem Naches in the early summer, before temperatures in the lower river rise sufficiently to be an impediment to migration (Mizell and Anderson 2006). Habitat choices seem to be driven more by velocity than by riparian cover, with tagged bull trout choosing water velocities where cover was provided by surface obfuscation and where prey was readily available (Mizell and Anderson 2006).

Telemetry studies in the upper Columbia River core areas have found some individual bull trout moving between core areas. Whether these migratory individuals spawned successfully and contributed to gene flow among core areas is unknown. Telemetry studies in the Yakima core area have not yet found a similar pattern of inter-core area movement.

An assessment of bull trout population genetic structure at the scale of the entire Columbia Basin indicated some apparent relationships among populations in the Yakima River, Upper Columbia River, and the Snake River (P. Spruell, pers. comm. 2004). Some populations in the Yakima River also were found to have unique genetic characteristics. Additional information about the potential for gene flow between the Yakima Core area and other core areas in the vicinity is needed.

Passage barriers within the Yakima Core Area have fragmented the bull trout metapopulation and limited migration to high quality spawning, foraging, and overwintering habitat. Of the 16 identified local populations, 12 are either completely or partially isolated. Across the core area, low numbers of migratory bull trout accompanied by lack of passage, limits the potential for genetic exchange and the reestablishment of local populations if local extirpation occurs. Fragmentation of the metapopulation is among the most potent threats to the persistence of the Yakima core area.

3.1.8 *Habitat Elements*

Large woody debris (LWD) is an integral component of productive aquatic habitat. In the Yakima core area, BOR Project operations and maintenance have impaired the recruitment of LWD in a number of ways. First and most obvious, headwater source areas are removed from the river continuum by storage dam embankments on the Yakima, Kachess, Cle Elum, Tieton, and Bumping Rivers. Further down the system, diversion structures impede the transport of LWD. Secondly, flow regulation and water withdrawals have contributed to impaired floodplain function along alluvial reaches of the river (Snyder and Stanford 2001). Cottonwoods (*Populus* spp.) are the primary species along the alluvial floodplain reaches of the Basin. Their growth and survival are vitally important to the aquatic ecosystem. Very little recruitment to cottonwood stands in the alluvial floodplain reaches of the Yakima and Naches Rivers is occurring primarily as a result of the highly modified annual flow regime of the Basin (Braatne and Jamieson 2001). This, coupled with floodplain disconnection and development, has decreased LWD supply and recruitment. A modeling effort to assess LWD recruitment rated less than half of the riparian areas in the Basin as having good potential (USFS 1996). The reduction in LWD recruitment has altered the structure and function of stream channels in the Basin. Importantly, habitat heterogeneity has been lost and the habitat complexity necessary to support healthy bull trout populations is lacking.

Pools are another important element in the habitat mosaic that allows for the full expression of all life history forms of bull trout (63 FR 31647). They provide important holding and resting areas for adult bull trout (Hoelscher and Bjornn 1989, Pratt 1992), as well as cover and winter refugia for fry and juveniles (63 FR 31647). In the Basin, large numbers of fluvial adult bull trout have often been observed holding in pools prior to spawning (James 2002; Mizell and Anderson 2006).

No comprehensive assessment of pool frequency and quality exists for streams in the Yakima River Basin. McIntosh et al. (1994) compared pool frequency in 80 km (48 mi) of tributaries in the Basin (Taneum Creek, Little Naches River, Rattlesnake Creek, and the American River) from data collected in the 1930s and 1940s, with that collected in 1990-1992. He found that pool frequency had increased in both managed and unmanaged areas. However, none of the surveyed areas were affected by flow regulation and the increases were attributed to a recovery from intensive sheep and cattle grazing that had occurred in the 1880s and early 1900s (McIntosh et al 1994). None of the streams surveyed by the U.S. Forest Service in the upper Yakima watersheds met expected levels of pool frequencies (USFS 1996).

Because the lower Yakima River has been heavily and negatively impacted by sediment deposition from agricultural drains, it is reasonable to assume that pool frequency and quality in the lower river has been significantly diminished. Given that the sources of LWD (a key element in pool formation) have been reduced by Project structures and operations, it is also reasonable to assume that pool frequency and quality have been impaired throughout the Project-affected portions of the Basin.

Off-channel habitat is another important habitat element providing rearing areas and refugia from high flows and predation. Flood control, road building, and bank stabilization projects as well as flow manipulation have isolated, reduced, or eliminated many off-channel habitats throughout the Yakima Basin (YSF&WPB 2004). Much of what remains is unsuitable due to elevated temperatures or poor water quality (YSF&WPB 2004).

3.1.9 *Channel Condition and Dynamics*

The width/depth ratios for regulated rivers are generally considered to be highly altered (decreased) from the natural condition because of flood plain development, placement of dikes and revetments, flow regulation, and disruptions of the sediment budget (Leopold et al. 1964, Dunne and Leopold 1978, Alabyan and Chalov 1998). All of these activities have occurred in the Yakima Basin. This situation is further exacerbated by the lack of LWD. Thus, it is reasonable to assume that the width/depth ratio in many reaches of the Yakima River system has decreased, resulting in stream channels that are narrower and incised with increased water velocities. These conditions reduce habitat quality, particularly for salmonids in their early life stages. Several reaches of the Yakima River have been identified where these effects are particularly severe, including those near the cities of Yakima and Ellensburg, and the upper river from the Easton Diversion Dam to the Teanaway River confluence (NPPC 2001).

Throughout the upper Yakima River Basin, relatively recent glacial activity filled valleys with large amounts of gravels, cobbles, and boulders. Vast alluvial floodplains developed, connected via a complex web of braided channels. This geologic template produced a series of alluvial groundwater basins separated by bedrock control points (e.g., Selah and Union Gaps) and canyons (e.g., Yakima Canyon) (Kinnison and Sceva 1963). Alluvial floodplains of this type were also found in varying magnitudes on numerous tributaries to the mainstem of the Yakima River (e.g., the Cle Elum, Teanaway, and Naches Rivers) and share the same composition and hydrologic function. Where alluvial floodplain habitats were once extensive throughout the Yakima River Basin, only a few remnant reaches now remain along the Yakima and Naches rivers (Snyder and Stanford 2001).

Historically, the hydrologic cycle of the Basin was characterized by extensive exchange between surface waters and the shallow alluvial groundwater aquifers (Kinnison and Sceva 1963). Spring runoff (and other high flow events) spread across the floodplain, distributing cold water into side channels that percolated into and recharged the alluvial aquifer. Alluvial aquifers served as hydrologic buffers that returned water to the Yakima River as baseflow later in the season after the cessation of snowmelt runoff. When coupled with an intact floodplain ecosystem, the lower Yakima River was a much different environment than what is observed today. Through annual flow manipulation, the BOR Project has significantly altered the natural hydrologic system within the Yakima River Basin by: (1) significantly reducing the extent of alluvial flood plain habitats and the role of alluvial aquifers in maintaining cold water in streams; (2) altering the runoff regime; and (3) disrupting the longitudinal, vertical, and horizontal connectivity of affected river systems within the Basin.

Many factors have led to the disconnection of alluvial flood plain reaches and the loss of off-channel habitat in the Basin, including: (1) revetments that isolate side-channel habitat; (2) de-watering associated with agricultural practices; (3) chemical and thermal pollution; and (4) extensive gravel mining that has severed extensive groundwater connectivity (Stanford et al. 2002). Channelization has had significant negative impact to the extent of floodplain connectivity that remains (YSF&WPB 2004).

Significant flood plain encroachment also has occurred in the Basin. On average, 66 percent of five alluvial reaches evaluated have been physically disconnected (Eitemiller et al. 2000). In the upper Yakima Basin, an average of 60 percent of the floodplain has been lost and from 57 to 85 percent of the floodplain in the lower Yakima River has been lost (Snyder and Stanford 2001). These encroachments have eliminated or isolated large areas of side channels and sloughs.

What little functional flood plain that remains has been, and continues to be, affected by BOR Project operations. River operations for irrigation and flood control alter the natural hydrograph by impounding high flow events. A common effect of these operations is a sharp reduction in the frequency with which high flow events recharge the alluvial flood plain aquifer. Truncation of flood peaks by capture in reservoirs also reduces the duration, magnitude, and spatial extent of flood plain inundation. This not only alters the quantity, quality, and timing of groundwater discharge to the river but also diminishes the availability, extent, and temporal duration of off-channel habitats. These changes in the pattern of floodplain inundation also have the undesirable effect of encouraging further commercial and residential development on the flood plain. Flood

plain disconnection combined with flow regulation (i.e., the inversion and truncation of the natural hydrograph) have dramatically reduced river flood plain interactions. The result has been a loss of horizontal and vertical connectivity, diminished habitat heterogeneity through the loss of off-channel habitat, and a general loss of ecosystem function.

Due to the detrimental impacts of past and present land use practices and the significant changes in the magnitude and duration of flow regimes, stream bank conditions throughout the Basin are also generally in a degraded condition (Stanford et al. 2002). Mining, logging, grazing, and road building activities have caused stream bank erosion, fine sediment delivery, and loss of riparian function. Accelerated stream bank erosion and fine sediment deposition have been documented in the upper Yakima River watershed (Cole, Gold, Little, and Big Creeks), the upper Cle Elum River watershed, and the South Fork Tieton River watershed (USFS 1998a, b, and 1999 a, b). Degraded stream banks and elevated fine sediment levels have also been reported in the Little Naches drainage (Dawson 1999). Streambank complexity has been greatly reduced in the Tieton and Naches River watersheds (YSF&WPB 2004).

3.1.10 *Flow/Hydrology*

The Yakima, Cle Elum, Tieton, Bumping, and Naches rivers are manipulated to maximize winter reservoir storage and summer irrigation deliveries according to the seasonal needs of irrigators (YBFWRB 2005). These operations result in streamflows across the subbasin that are mostly out of phase with the life history requirements of native salmonids. Reservoir operations combined with diversions across the Yakima Basin have inverted and truncated the natural pattern of streamflow so that river systems are now spatially and temporally discordant with their surrounding watersheds. The biota of these systems has also suffered because flow regulation patterns are less than optimal for native salmonids (Fast et al. 1991) and floodplain riparian species (Braatne and Jamieson 2001). Summer and fall drawdown of Lake Kachess, Lake Keechelus, and Rimrock Lake (Tieton Reservoir) obstructs or prevent access to tributaries by adult bull trout on spawning migrations and strands juvenile bull trout (YBFWRB 2005).

Below the storage reservoirs, habitat degradation associated with flow regulation has likely adversely impacted bull trout. Several features of the regulated hydrographs for various river reaches in the basin are highly unnatural. With the exception of the upper Naches River (above the Tieton River confluence), the magnitude of flows resulting from rain-on-snow events and snow-melt runoff has been significantly reduced by water storage in reservoirs. In contrast, the magnitude of flows during the peak of the irrigation season from July through mid-September is greatly elevated in some areas of the Basin, particularly in the upper Yakima River arm. However, during this same time period, the lower Yakima River below the Sunnyside Diversion Dam experiences lower than natural flows due to water withdrawals for irrigation.

Flow regulation during this late summer/early fall period may be most problematic for bull trout in the Basin. This is due primarily to the operational procedure known as "flip-flop". The purpose of the "flip-flop" operation is to encourage spring Chinook salmon to spawn at relatively low flows so that less water is required during the winter to keep the redds covered. This water operation also reduces impacts on irrigation water supply during the next season. In early

September the annual "flip-flop" operation in the Yakima Basin involves reducing flows in the upper arm of the Yakima River and increasing flows in the Naches River with increased water releases from Rimrock Reservoir.

The extreme flow modification in the Keechelus Dam to Easton Diversion Dam reach, beginning in late June and extending through September, likely has had an adverse effect on bull trout survival and reproduction. From 1981 through 2002, regulated flows have averaged 682, 918, and 440 cfs for the months of July, August, and September, respectively (source: BOR, Yakima Field Office, Hydromet database). These flows are 3.7, 9.3, and 4.7 times the average estimated unregulated discharge for those months, respectively. From 1997 through 2002, the average daily flow in September (a month when bull trout would be staging to spawn or possibly spawning) declined considerably to 83 cfs, very close to the flow which would occur under unregulated conditions (93 cfs). This was done to accommodate the increasing numbers of spring Chinook spawning in the reach. However, average daily flows during July and August strayed further from natural unregulated flows in these years with an average daily discharge of 992 cfs in July (809 cfs over the average daily estimated unregulated flow of 183 cfs from 1981-2001) and 977 cfs in August (878 cfs over the average daily estimated unregulated flow of 99 cfs from 1981-2001).

For many years, flows in this reach were arbitrarily reduced following the irrigation season. As recently as 1992 this reach experienced periods when no water was released from Keechelus Dam at all. Although this condition has not occurred since 1995, flows in January and March averaged just 15 cfs daily. Since 1999, winter conditions have improved considerably. The winter minimum flow is set by the BOR Field Office manager after an appropriate flow recommendation has been made based on a field survey. Since spawning flows have been provided in the neighborhood of 80-100 cfs, winter minimum flows have generally been kept at 70 cfs or higher.

When flip-flop occurs in early September, this release pattern is switched and late season irrigation demands are met primarily from Rimrock Reservoir on the Naches River side for about 40 days. The effect of this operation is the complete inversion of the flow regimes on both sides of the basin. The high flows in the upper Yakima River which have been maintained since July are reduced to levels very close to those which would occur under unregulated conditions. On the Cle Elum River, the change is most profound as flows drop an order of magnitude in the fall. In the Tieton River, the effect is the opposite as flows increase four to five times over the level at which they were held much of the summer. At the end of the irrigation season, usually around October 20, the Project shifts emphasis to water storage and flows in the Tieton River are often reduced below 20 cfs. Flows are usually reduced on the Yakima River side of the basin as well, sometimes by as much as 50 percent, but they must remain adequate to protect spring Chinook redds. On both sides of the basin, these unstable and abnormal flow patterns have likely had a negative impact on fluvial bull trout. Successful spawning under these conditions is unlikely in the upper Yakima, Cle Elum and Tieton Rivers. Habitat stability for other life stages of bull trout and for other taxa in the aquatic community, including prey species, may also be seriously compromised under these operating conditions. Effects of these flow modifications on various habitat pathways have been described above.

Water withdrawals from streams by irrigation diversions within the basin contribute to low flow conditions in some streams (i.e., Manastash, Taneum, Naneum, Ahtanum, and Cowiche Creeks and the Tieton River), and seasonal dewatering of others. Seven mainstem irrigation diversion dams (Easton, Town Ditch, Wapato, Sunnyside, Prosser, Yakima Tieton Irrigation District, and Horn Rapids) have contributed to altered flow regimes within the basin (Snyder and Stanford 2001). Low flows can inhibit bull trout spawning migrations and result in the stranding of juvenile bull trout in Ahtanum and Rattlesnake Creeks and Teanaway River (E. Anderson, WDFW, 2002, pers. comm.).

3.1.11 *Watershed Condition*

Forest practices, agriculture, urbanization, flow regulation, along with diking and streambank protection have simplified stream channels, damaged riparian habitat, and impaired the ability of streams to interact with their floodplains and aquifers across the Yakima subbasin (YBFWRB 2005). Gravel resources have been mined up to the river's edge, urban development has encroached into the river corridor, and floodplain and riparian habitat has become tracts of agricultural land (YBFWRB 2005).

Bull trout are less likely to use streams for spawning and rearing in areas with high road density, and are typically absent at mean road densities above 1.1 kilometer per square kilometer (1.7 miles per square mile) (Quigley and Arbelbide 1997). The extensive road network throughout the Yakima core area has generally reduced habitat quality. In particular, the Teanaway and Little Naches drainages have high road densities and corresponding reductions in habitat suitability.

Before 1905, riparian corridors and habitat were estimated to have covered 2 percent of the land area in the Yakima Basin; that area has decreased to 0.5 percent currently (Quigley and Arbelbide 1997). Healthy riparian areas contribute to the amount of LWD in streams, to channel dynamics, to nutrient loads and, therefore, to community structure, and to lower water temperature; these factors can have far-reaching effects both upstream and downstream (Bolton and Shellberg 2001). Loss of these functions is typically associated with reduced productivity of fish populations.

The Upper Yakima River, Upper Naches River, Ahtanum Creek, Teanaway River, and Taneum Creek watersheds all have long histories of forest management. For example, in the Upper Yakima, twenty-six percent of the watershed is an early seral (i.e., seedling/sapling) stage primarily as a result of timber harvest (USFS 1999b). The watershed has many roads constructed for timber harvest purposes, with a road density of 2.6 kilometers per square kilometer (4.1 miles per square mile) (USFS 1999b). Detrimental impacts from timber management can include the removal of LWD, and the reduction in riparian vegetation which results in water temperature increases, accelerated erosion, and de-stabilization of stream channels.

Past forest management has led to changes in natural disturbance regimes. Past and ongoing fire suppression, increased tree densities and forest fuel continuity, and residential development along the wildland-urban interface, are among the factors that can lead to larger and more severe wildfires. Uncharacteristically severe wildfires can lead to levels of increased mass wasting,

increased sediment delivery to streams, reduced stream shade that increases water temperature, and other effects to the aquatic environment that exceed the natural range of variation and physiologic tolerance levels of bull trout. Wildfire can improve aquatic habitats and benefit fish populations in natural situations of well-connected habitats and mixed-severity fire. However, isolated populations with limited access to suitable habitat, like those in the Yakima core area, can be extirpated by exposure to severe wildfire or other extreme disturbance events.

The Ahtanum, Teanaway, and Tieton watersheds within the Basin also have a long history of cattle and sheep grazing dating back to the 1800's (NPPC 2001). Improperly managed livestock grazing can degrade bull trout habitat by removing riparian vegetation, which destabilizes streambanks, widens stream channels, promotes incised channels, lowers water tables, reduces pool frequency, increases soil erosion, and alters water quality (Howell and Buchanan 1992, Mullan et al. 1992, Overton et al. 1993). These effects can reduce overhead cover, increase summer water temperatures, and increase sediment in spawning and rearing habitats. Recently, illegal grazing has resulted in take of bull trout in the Tieton River and Ahtanum Creek areas due to cattle trampling bull trout redds (Jeff Krupka, USFWS, 2003, pers. comm.) .

The expansion of agriculture and the associated use of pesticides and herbicides in the Basin have resulted in the degradation of water quality within streams and rivers that are adjacent to, and downstream of, agricultural fields. Currently, 188,259 hectares (465,000 acres) are under irrigation in the Basin. The Yakima River Basin ranks fifth nationally in total agricultural production (USBR 1999). In addition to degraded water quality, bull trout habitat within the Basin has been adversely affected by irrigation diversions and water withdrawals (Snyder and Stanford 2001).

Historically, hard rock and placer mining occurred at several sites within the Basin. These mining operations dredged, diked, and confined stream channels and leached toxic heavy metals such as mercury into the stream channels. Although no large mines have been constructed recently, there is a limited amount of small-scale suction dredging and hard rock mining still occurring in several watersheds including the Little Naches, and Cle Elum (Dawson 1999, USFS 1999a). Suction dredge mining may alter the substrate composition and benthic insect community composition where in-channel mining activity occurs (Harvey and Lisle 1998). Studies indicate that such changes have occurred (Stanford et al. 2002) but mining has not been specifically identified as a root cause. In the upper Kachess River, a third-order tributary to Kachess Lake, tailings left from copper mining activities around the turn of the century have washed down during rainstorms (Meyer 2002). Now, because of the massive quantities of alluvial material that have been deposited, these tailings cause the frequent dewatering of the upper Kachess River in the summer and fall.

Gravel mining has had some unknown level of effect on bull trout in the Yakima Basin. The Gold Creek gravel pit has undoubtedly lowered sub-surface water levels to an unknown degree and likely has contributed to the frequent de-watering of Gold Creek. The Swauk Creek drainage has been heavily mined but bull trout have only been rarely found there (Judy De La Vergne, USFWS, 2003, pers. comm.). The Selah Pit near Yakima is the largest in the State of Washington and covers over 93 hectares (230 acres).

Fisheries management in the Yakima core area has also had detrimental effects on bull trout. Heavy sport angling pressures occur in parts of the Yakima core area due to a combination of rainbow trout stocking, high catch limits, fishing regulations that allow the use of bait, and easy public access to the mainstem and tributaries. Because bull trout are aggressive feeders and highly susceptible to sport fishing, incidental catch of bull trout and associated injury and mortality has probably reduced survivorship of adult fish. In addition, poaching has been documented or suspected in Gold Creek, Box Canyon Creek, Deep Creek, South Fork Tieton River, and Indian Creek. Several non-native fish species have been introduced to the Basin, and some continue to be stocked to support sport fisheries. Introduced species include brook trout, brown trout, lake trout, bass, catfish, bluegill, sunfish, and crappie. All these have likely adversely affected bull trout populations through a combination of hybridization, competition, and predation.

Specific areas within the Yakima River Basin have grown in popularity as a preferred area for home sites. As the human population increased, more impacts to riparian areas and water quality have also increased (NPPC 2001). Damage includes increases in nutrient loading from septic systems and chemical applications, alterations to channel morphology, and effects from road construction. Areas where flood plain development is proceeding most rapidly are Lower Little Creek and the Naches River (E. Anderson, WDFW, 2002, pers. comm.).

3.1.12 *Summary of Habitat Conditions*

The Service has developed a methodology for risk assessment of bull trout core areas for use in section 7 consultation (USFWS 2006, 2007; see Appendix C). This method integrates the condition of all MPI habitat pathways and indicators and includes consideration of the presence of brook trout as an indicator of ecological and genetic threats (see Rieman et al. 2006). Applying this approach to the Yakima core area we find that habitat conditions for spawning and rearing areas for all local populations are at high risk (i.e., not properly functioning) for the pathways of habitat access, channel condition, flow/hydrology, and brook trout presence and are at moderate risk (i.e., functioning at risk) for the pathways of water quality and habitat elements. This is generally due to blocked migratory corridors, loss of complex river habitat, altered channel and watershed conditions, and extreme hydrologic patterns. The condition of feeding, migratory, and overwintering habitat in the Yakima Core Area is at high risk (i.e., not properly functioning) for bull trout because of poor water quality, lack of adequate habitat complexity, poor channel complexity, degraded instream flow or hydrology, highly disturbed watershed conditions, and the widespread presence of brook trout.

3.1.13 *Other Factors Affecting the Bull Trout's Environment in the Yakima Core Area*

Restoration programs which include riparian restoration, restoration of fish passage at barriers, and habitat improvement projects are occurring in the Yakima Core Area. Local watershed groups have coordinated to complete stream habitat work along the mainstem Yakima River and its tributaries and are working with the U.S. Forest Service to complete culvert repairs. Most large culverts on the national forest land have been replaced with open bottom arches or bridges to facilitate fish passage. The Plum Creek Timber Company Cascades Habitat Conservation Plan (HCP) was developed on lands in the upper Yakima Basin. The HCP has provisions for timber harvesting and other land management Best Management Practices that benefit aquatic habitats and bull trout. Grazing problems in Ahtanum Creek on Washington Department of Natural

Resources lands and Ahtanum Irrigation District lands have been reduced with the placement of a fence along riparian areas adjacent to most of the spawning habitat. Grazing problems on National Forest lands in the South Fork Tieton have been reduced with changes to grazing allotment management plans that reduce cow access to spawning areas and reduce impacts to riparian areas. The Forest Practices HCP (FPHCP) is expected to have a significant beneficial effect on access and connectivity through accelerated identification and remediation of fish-passage barriers on private forest lands. Improved access and connectivity across FPHCP lands is expected to benefit migrations as well as allow re-occupancy of locations where extirpation has occurred.

Implementation of research and restoration projects under ESA Section 10(a)(1)(A) permits have resulted in direct effects to bull trout due to capture and handling and indirect mortality (BOR, WDFW, EPA, Central Washington University, Yakama Nation, and USFWS fisheries studies). Although projects associated with the restoration programs may result in long-term benefits for bull trout and their habitat, all entities listed above holding permits engaged in research activities that resulted in take of bull trout. ESA Section 6 Habitat Acquisition funds have been used to acquire and protect from development multiple private parcels with riparian frontage, totaling over 8,000 acres in the Upper Yakima and Tieton watersheds. These efforts complemented efforts by the Cascades Conservation Partnership which purchased over 37,000 acres of private lands and transferred them to public ownership, mostly in the Upper Yakima, Taneum, and Teanaway watersheds.

Many non-Federal actions have occurred in the Yakima Core Area since the listing of bull trout. Activities such as emergency flood control, development, and infrastructure maintenance are conducted on a regular basis and affect riparian and instream habitat. Hydraulic Permits issued by the State also affect bull trout and bull trout habitat. Recent land-use changes from agriculture to urban development along the riparian areas may also be affect bull trout and bull trout habitat. County permits have likely increased for construction of homes in floodplain and riparian areas. The aggregate effects of all these activities on bull trout populations and the quantity and quality of bull trout habitat are uncertain. Despite large restoration efforts, available information about bull trout population performance suggests overall conditions in the core area are stable or declining.

3.1.14 *Threats to the Bull Trout in the Yakima Core Area*

The preceding description of the environmental baseline in the Yakima core area indicates threats to bull trout persistence are numerous and varied. The presence and ongoing operations of the Bureau of Reclamation's Yakima Basin Project, agricultural activities, and urban and rural development with rapid human population growth, are among the most pervasive challenges to the integrity of aquatic habitats and bull trout populations. The following list of threats suggests the wide range of restoration activities needed to meet the conservation needs of bull trout in the core area. Details about the mechanisms underlying these threats and their intensity are available in the Draft Bull Trout Recovery Plan and accompanying documents (USFWS 2002a) the Yakima Subbasin Plan (YSF&WPB 2004), and the Service's 5-year review (USFWS 2008).

- Disruption of migration and alteration of hydrology due to dams. Threats associated with these major dams include: fragmentation of populations; entrainment; altered flow regimes and water temperatures downstream of the dams; prey base alterations; changes

in habitat characteristics such as cover, holding pools, and complexity, both below the dams and along the shorelines of the reservoirs that have dramatic fluctuations in water surface elevations; and poor access from drawn down reservoirs to spawning tributaries.

- Low population size of isolated populations
- Loss of genetic diversity
- Human population in the basin is projected to increase about 45 percent by 2020 (YSF&WPB 2004). Impacts to habitat quantity and quality from agricultural, residential, commercial, and industrial development are likely to increase as the population increases. These impacts include increased chemical contamination, and reduced riparian area function, among many others.
- Irrigation diversions and associated water withdrawals reduce instream flow (sometimes dewatering stream reaches), increase water temperatures, contribute to irrigation return flows containing increased levels of sediment, nutrients, and contaminants, and cause entrainment. Specific areas impacted include: Yakima River Mainstem Lower Rattlesnake Creek; Big Creek; Lower Taneum Creek; Teanaway River; and Ahtanum Creek.
- Past logging, and logging-related activities (especially road building), have degraded habitat conditions and habitat access in the upper Yakima River, Cle Elum River, Taneum River, Ahtanum Creek, Teanaway River, Naches River, and the Tieton River.
- Livestock practices have degraded bull trout habitat, especially in Ahtanum Creek, Teanaway River, and the Tieton River.
- The combination of hatchery-stocked rainbow trout, large catch limits, use of bait, and easy public access has resulted in high angling pressures that may result in angling-related injury and mortality. In addition, poaching has been identified as a serious concern in Gold Creek, Box Canyon Creek, Deep Creek, South Fork Tieton River, and Indian Creek.
- Introduced non-native fish species leading to increased competition, predation, and hybridization
- Increased risk of uncharacteristically severe wildfire.
- Mining-related reductions in water quality and channel complexity.
- High mortality rates as bull trout pass through the drawdown zones of reservoirs, where entry or exit of spawning streams entails passing a gauntlet of predators surrounding a shallow stream with no cover. Aggradation of these drawdown zones can also lead to passage problems addressed by ad hoc or emergency solutions that have limited effectiveness.

The variety and intensity of this assemblage of threats makes the persistence of bull trout in the Yakima core area questionable (USFWS 2008, pg. 30). This pattern of threats closely resembles those associated with extirpation of bull trout populations (Rieman and McIntyre 1993) as well as extirpation of populations of anadromous salmon and other native fishes of the Pacific Northwest (Frissell 1993). Restoring connectivity among habitats and local populations, aggressive floodplain habitat restoration, and return of flow regimes to more natural patterns would all contribute toward increasing the likelihood that bull trout in the Yakima core area might persist and eventually contribute to the recovery of the Columbia River interim recovery unit.

3.2 Environmental Baseline in the Teanaway Watershed

The Teanaway River basin lies in the upper reaches of the larger Yakima River watershed east of the Cascade crest near the town of Cle Elum, Washington. This watershed drains an area of approximately 207 square miles. The climate consists of warm, dry summers and cold, snowy winters. Annual precipitation ranges from 20 inches near the mouth of the Teanaway River (elevation 1,800 feet) to 90 inches in the high mountains (elevation 6,000 feet). Peak runoff events are of two kinds: rain-on-snow precipitation events between November and February, and high flows associated with spring snowmelt in April and May (USFS, 1998). Streamflow information is available for the U.S. Bureau of Reclamation gage located on the Teanaway River below the confluence of the three major forks. The gage is upstream of major irrigation diversions. The 1971-1998 period of records show a peak flow of 8,000 cfs and a low flow of 6 cfs, with an average annual peak of 1,000 cfs and an average annual 7-day low of 15 cfs.

Major land uses and ownership can generally be described by dividing the watershed into thirds. The upper one-third of the watershed lies in the Wenatchee National Forest and is managed by the U.S. Forest Service. Much of the middle one-third of the watershed is owned and managed by private timber companies, with land adjacent to the Middle and North forks often in agricultural or range land. The lower one-third of the watershed, below the West, Middle, and North forks, contains hay, feed crops, and horses near the mainstem, and timber management in the surrounding hills.

Historically, the Teanaway River was one of the top producers of spring Chinook, steelhead and coho in the Yakima basin. Today, with predictions of decreasing snowpack and irrigation demands, the Teanaway struggles to supply enough water to overcome the low-flow barriers that limit migration, spawning and rearing of native anadromous fish.

The mainstem, Middle, North, and West Forks are all included on the Clean Water Act 303(d) impaired water quality list for temperature. The primary factors limiting bull trout production in the Teanaway River are low stream flows and high water temperatures.

Despite these conditions, recent studies indicate that the Teanaway River has some of the highest restoration potential in the Yakima Basin, with the capacity to double its productivity, given the right restoration activities.

3.2.1 *Bull Trout Population Characteristics in the Teanaway Watershed*

Washington Department of Fish and Wildlife (WDFW, 1998) found that there were a total of 54 bull trout in the North Fork Teanaway River in 1994 and 10 bull trout in 1997. These estimates were based on snorkel surveys and include all size and age classes.

Within the Teanaway River, the bull trout local population primarily uses habitat within the North Fork Teanaway River and the mainstem and DeRoux Creek. Limited spawning occurs in the North Fork Teanaway River just upstream of DeRoux Creek where redd counts have yielded only 0-2 redds from 2005-2009 (Table 1). Bull trout have also been observed in Jungle and Jack

Creeks. Although the habitat appears to be suitable for bull trout in the West and Middle Forks, no bull trout have been found in these streams. Bull trout in the North Fork Teanaway River are likely a mix of both small resident forms and larger fluvial forms.

3.2.2 *Factors Affecting the Species' Environment in the Action Area*
In the action area specifically, impaired fish habitat is mostly due to degraded channel conditions and reduced stream flows. These conditions are most severe in the lower watershed, which includes the migratory corridor which could connect the Teanaway River local population to the others in the Yakima basin.

The majority of the lower end of the Teanaway River has been channelized, armored and/or diked, greatly reducing channel complexity, stability and sinuosity. Sparse riparian corridors remain throughout the lower reach. The streambed is degrading partly due to the channelization and diking, and partly due to the logging activities in the upper watershed. The stream has extremely low flows in late summer and early fall.

According to the Washington Department of Ecology's 303(d) list, the Teanaway River is listed for high water temperature concerns between River Miles (RM) 0 – 3.8 (the lower portion of the river). This is most likely due to the modifications humans have made to the stream channel and watershed (agriculture, urbanization, riparian vegetation removal, logging, etc.). Soils are generally deep with higher erodibility in the lower areas, particularly near the channels of the three forks of the Teanaway River (Tri-County Water Resources Agency 2001). The Teanaway River has been downcutting leading to increased streambank erosion and accumulations of fine sediments in stream gravels. This is the result of past timber harvest and concentrated peak flows in the watershed. (Tri-County Water Resources Agency 2001).

There are no known structural barriers on the Teanaway River, but there may be some temporary barriers caused by wing dams near irrigation diversions or culverts that are not properly placed or sized. However, fish passage is negatively affected by low flow conditions in the late summer and early fall (Tri-County Water Resources Agency 2001).

Large wood is consistently lacking throughout the Teanaway River with selective logging reducing the riparian stand densities and cattle grazing limiting the success of young confer within the riparian area (Tri-County Water Resources Agency 2001). Additionally, in some areas, several commonly occurring soil types do not favor tree production. Large wood is present at the project site within the current log/rock structure placed by the landowner during the 2009 flood event. With the lack of large wood within the Teanaway River, it is assumed that pool quantity and quality has decreased.

Some channel areas in the Teanaway River are entrenched or confined so as to limit side channel development and access. Within the action area there is a remnant side channel that is attached to the Teanaway River during high flow events on the downstream end. Historically, the Teanaway River floodplain contained numerous sloughs, side channels and forested wetlands. Today, the majority of Teanaway River has been diked and/or channelized, and the floodplain vegetation has been removed. All of these activities can eliminate important habitat areas used for refugia.

At the Project site, the streambank is a combination of a wood and rock barb and eroding soil. The landowner's property is on an outside bend which should have some natural erosion taking place. The left bank, where the Project will occur, is approximately 9-10 feet high. The riparian vegetation, that the landowner maintained, was washed away during the 2009 flood event. Streambanks should not have rip rap as a component; however due to changes in land use historically, the watershed has changed, and many landowners along the Teanaway River have placed rip rap on the banks as protection against flooding. There is no riprap present at the Project site; however there are some old rock barbs that are being incorporated into the project. A berm or dike was also built historically just upstream of the landowner's property and is maintained by current landowners.

3.3 Likelihood of Species Presence in the Action Area

All Project activities will occur at a location downstream from spawning and rearing habitat. The proposed action will occur from mid-August through mid-October. During this interval, bull trout are extremely rare in this area, most likely because of very small population size and habitat appears to be sub-optimal for bull trout survival in this area at that time. However, the Project location is within an area used for migration, feeding, and possibly overwintering by adult and sub-adult bull trout, and Project activities may temporally overlap with transient bull trout activity in the area.

In summary, because bull trout are scarce in the Teanaway River basin and spawning and rearing occurs upstream of Project activities, juvenile bull trout are not expected to be present in the action area. Due to the low population within the Teanaway River drainage, it is probably extremely rare for adult bull trout to be present in the action area during the time of year when the Project will occur.

3.4 Global Climate Change

Global climate change has the potential to affect the baseline condition of bull trout habitat at all scales from the coterminous U.S. to the sub-watershed and action area. Available evidence also indicates climate change effects are reasonably certain to continue into the foreseeable future. Consequently, climate change could be addressed under multiple headings in this BO (e.g., rangewide status of the species, environmental baseline, and cumulative effects). Rather than scatter our discussion of this important topic throughout the BO, we consolidate in this section our consideration of how climate change may alter baseline conditions across scales.

Climate change is one of the most significant ongoing effects to baseline conditions for bull trout and their associated aquatic habitat throughout the state of Washington. Climate change, and the related warming of global climate, has been well-documented in the scientific literature (Bates et al. 2008; ISAB 2007). Evidence includes increases in average air and ocean temperatures, widespread melting of snow and glaciers, and rising sea level. Given the increasing certainty that climate change is occurring and is accelerating (Bates et al. 2008; Battin et al. 2007), we can no longer assume that climate conditions in the future will resemble those in the past.

Climate change has the potential to profoundly alter the aquatic habitat through both direct and indirect effects (Bisson et al. 2003). Direct effects are evident in alterations of water yield, peak

flows, and stream temperature. Some climate models predict 10 to 25 percent reductions in late spring, summer, and early fall runoff amounts in coming decades. Indirect effects, such as increased vulnerability to catastrophic wildfires, occur as climate change alters the structure and distribution of forest and aquatic systems. Observations of the direct and indirect effects of global climate change include changes in species ranges and a wide array of environmental trends (ISAB 2007; Hari et al. 2006; Rieman et al. 2007). In the northern hemisphere, ice-cover durations over lakes and rivers have decreased by almost 20 days since the mid-1800s (WWF 2003). For cold-water associated salmonids in mountainous regions, where upper distribution is often limited by impassable barriers, an upward thermal shift in suitable habitat can result in a reduction in size of suitable habitat patches and loss of connectivity among patches, which in turn can lead to a population decline (Hari et al. 2006; Rieman et al. 2007).

Climate change is already affecting the frequency and magnitude of fires, especially in the warmer, drier regions of the west. To further complicate our understanding of these effects, the forest that naturally occurred in a particular region may or may not be the forest that will be responding to the fire regimes of an altered climate (Bisson et al. 2003). In several studies related to the effect of large fires on bull trout populations, bull trout appear to have adapted to past fire disturbances through mechanisms such as dispersal and plasticity. However, as stated earlier, the future may well be different than the past and extreme fire events may have a dramatic effect on bull trout and other aquatic species, especially in the context of continued habitat loss, simplification and fragmentation of aquatic systems, and the introduction and expansion of exotic species (Bisson et al. 2003).

In the Pacific Northwest, most models project warmer air temperatures and increases in winter precipitation and decreases in summer precipitation. Warmer temperatures will lead to more precipitation falling as rain rather than snow. As the snow pack diminishes, stream flow timing will change, and peak flows will likely increase in volume. Higher ambient air temperatures will likely cause water temperatures to rise (ISAB 2007). Data from long-term stream monitoring stations in western Washington indicate a marked increasing trend in temperatures in most major rivers over the past 25 years (WDOE 2007).

There is still a great deal of uncertainty associated with predictions of timing, location, and magnitude of climate change. It is also likely that the intensity of effects will vary by region (ISAB 2007). Research indicates that temperatures in many areas will continue to increase due to the effects of global climate change. According to model predictions, average temperatures in Washington State are likely to increase between 1.7 °C and 2.9 °C (3.1 °F and 5.3 °F) by 2040 (Casola et al. 2005).

Bull trout rely on cold water throughout their various life stages and increasing air temperatures likely will cause a reduction in the availability of suitable cold water habitat. For example, ground water temperature is generally correlated with mean annual air temperature and has been shown to strongly influence the distribution of char species. Groundwater temperature can also

be linked to bull trout selection of spawning sites and has been shown to influence the survival of embryos and early juvenile rearing of bull trout (Rieman et al. 2007). Increases in air temperature are likely to be reflected in increases in both surface and groundwater temperatures.

Migratory bull trout can be found in lakes, large rivers and marine waters. Effects of climate change on lakes are likely to impact migratory adfluvial bull trout that seasonally rely upon lakes for their greater availability of prey and access to tributaries. Climate-related warming of lakes will likely lead to longer periods of thermal stratification, forcing coldwater fish such as bull trout to be restricted to the bottom layers for greater periods of time. Deeper thermoclines resulting from climate change may further reduce the area of suitable temperatures in the deeper depths of lakes and intensify competition for food (WWF 2003).

Bull trout require very cold water for spawning and incubation. Suitable spawning habitat is often found in accessible higher elevation tributaries and headwaters of rivers. However, impacts on hydrology associated with climate change will cause shifts in timing, magnitude, and distribution of peak flows that are also likely to be most pronounced in these high elevation stream basins (Battin et al. 2007). The increased magnitude of winter peak flows in high elevation areas is likely to affect spawning and incubation habitat for bull trout and Pacific salmon. Although lower elevation rivers are not expected to experience as severe an impact from alterations in stream hydrology, they are generally not cold enough for bull trout spawning, incubation, and juvenile rearing.

As climate change progresses and stream temperatures warm, thermal refugia will be critical to ensure the persistence of bull trout and other species dependent on cold water. Thermal refugia are important for providing bull trout with patches of suitable habitat while allowing them to migrate through, or to make foraging forays into, areas with above optimal temperatures. Juvenile rearing may also occur in waters that are at or above optimal temperature, but these rearing areas are usually in close proximity to colder tributaries or other areas of cold water refugia (USEPA 2003).

Climate change is and will be an important factor affecting bull trout distribution and population dynamics. As distribution contracts, patch size decreases and connectivity is truncated; populations that are currently connected may become thermally isolated, which could accelerate the rate of local extinction beyond that resulting from changes in stream temperature alone (Rieman et al. 2007). In areas with already degraded water temperatures or where bull trout are at the southern edge of their range, they may already be at risk of impacts from current as well as future climate change. As these trends continue, the conservation role of bull trout populations in headwaters habitats may become more significant. Long-term persistence of bull trout may only be possible in these headwater areas that provide the only suitable habitat refugia.

4 STATUS OF BULL TROUT CRITICAL HABITAT

Critical habitat is defined in section 3(5)(A) of the Act as "the specific area within the geographic area occupied by the species on which are found those physical or biological features essential to the conservation of the species, and that may require special management considerations or protection, and specific areas outside the geographical area occupied by a

species at the time it is listed, upon determination that such areas are essential for the conservation of the species." The Act defines conservation as the procedures necessary to bring about the eventual recovery and delisting of a listed species.

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat within 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act and the August 6, 2004, Ninth Circuit Court of Appeals decision in Gifford Pinchot Task Force v. U.S. Fish and Wildlife Service (No. 03-35279) to complete the following analysis with respect to critical habitat.

4.1 Legal Status and History of Bull Trout Critical Habitat

The Service published a final critical habitat designation for the coterminous United States population of the bull trout on October 18, 2010 (70 FR 63898), replacing the previous final critical habitat designation published in 2005; the 2010 final rule became effective on November 17, 2010. A document providing the biological rationale for inclusion of each critical habitat unit (CHU) in the designation was also developed to support the rule and is available on our website (http://www.fws.gov/pacific/bulltrout). The scope of the designation involved the species' coterminous U.S. range, as listed on November 1, 1999 (50 FR 63898), which includes a total of five interim recovery units (previously known as distinct population segments; the Jarbidge River, Klamath River, Columbia River, Coastal-Puget Sound, and Saint Mary-Belly River) [1]. Rangewide, the Service designated critical habitat in five states in a combination of reservoirs/lakes and streams/shoreline (Table 2). Designated bull trout critical habitat is of two primary use types: 1) spawning and rearing (SR), and 2) foraging, migration, and overwintering (FMO).

The 2010 revision increases the amount of designated bull trout critical habitat by approximately 76 percent for miles of stream/shoreline and by approximately 71 percent for acres of lakes and reservoirs compared to the 2005 designation. The 2010 rule also identifies and designates as critical habitat approximately 1,323.7 km (822.5 miles) of streams/shorelines and 6,758.8 ha (16,701.3 acres) of lakes/reservoirs of unoccupied habitat to address bull trout conservation needs in specific geographic areas in several areas not occupied at the time of listing. No unoccupied habitat was included in the 2005 designation. These unoccupied areas were determined by the Service to be essential for restoring functioning migratory bull trout populations based on currently available scientific information. These unoccupied areas often include lower main stem river environments that can provide seasonally important migration habitat for bull trout. This type of habitat is essential in areas where bull trout habitat and population loss over time necessitates reestablishing bull trout in currently unoccupied habitat areas to achieve recovery.

[1] The Service's 1999 coterminous listing rule identified five interim recovery units (50 CFR Part 17, pg. 58910) and our five year review recommended re-evaluation of these units based on new information (USFWS 2008, pg. 9). Our subsequent critical habitat designation described six draft recovery units (75FR63927). Until the bull trout draft recovery plan is finalized, the five interim recovery units will be used for purposes of section 7 jeopardy analyses. The adverse modification analysis in this biological opinion does not rely on recovery units, relying instead on the newly listed critical habitat units and subunits.

Critical habitat includes the stream channels within the designated stream reaches and has a lateral extent as defined by the bankfull elevation on one bank to the bankfull elevation on the opposite bank. Bankfull elevation is the level at which water begins to leave the channel and move into the floodplain and is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series. If bankfull elevation is not evident on either bank, the ordinary high-water line must be used to determine the lateral extent of critical habitat. The lateral extent of designated lakes is defined by the perimeter of the waterbody as mapped on standard 1:24,000 scale topographic maps. The Service assumes in many cases this is the full-pool level of the waterbody. In areas where only one side (one bank) of the waterbody is designated, the mid-line of the waterbody represents the lateral extent of critical habitat.

Table 2. Stream/shoreline distance and reservoir/lake area designated as bull trout critical habitat by state.

State	Stream/Shoreline Miles	Stream/Shoreline Kilometers	Reservoir /Lake Acres	Reservoir/ Lake Hectares
Idaho	8,771.6	14,116.5	170,217.5	68,884.9
Montana	3,056.5	4,918.9	221,470.7	89,626.4
Nevada	71.8	115.6	-	-
Oregon	2,835.9	4,563.9	30,255.5	12,244.0
Oregon/Idaho	107.7	173.3	-	-
Washington	3,793.3	6,104.8	66,308.1	26,834.0
Washington (marine)	753.8	1,213.2	-	-
Washington/Idaho	37.2	59.9	-	-
Washington/Oregon	301.3	484.8	-	-
Total	19,729.0	31,750.8	488,251.7	197,589.2

In marine nearshore areas, the inshore extent of critical habitat is the mean higher high-water (MHHW) line, including the uppermost reach of the saltwater wedge within tidally influenced freshwater heads of estuaries. The MHHW line refers to the average of all the higher high-water heights of the two daily tidal levels. Marine critical habitat extends offshore to the depth of 10 meters (m) (33 ft) relative to the mean low low-water (MLLW) line (zero tidal level or average of all the lower low-water heights of the two daily tidal levels). This area between the MHHW line and minus 10 m MLLW line (the average extent of the photic zone) is considered the habitat most consistently used by bull trout in marine waters based on known use, forage fish availability, and ongoing migration studies and captures geological and ecological processes important to maintaining these habitats. This area contains essential foraging habitat and migration corridors such as estuaries, bays, inlets, shallow subtidal areas, and intertidal flats.

Adjacent shoreline riparian areas, bluffs, and uplands are not designated as critical habitat. However, it should be recognized that the quality of marine and freshwater habitat along streams, lakes, and shorelines is intrinsically related to the character of these adjacent features, and that human activities that occur outside of the designated critical habitat can have major effects on physical and biological features of the aquatic environment.

The final rule continues to exclude some critical habitat segments based on a careful balancing of the benefits of inclusion versus the benefits of exclusion. Critical habitat does not include: (1) waters adjacent to non-Federal lands covered by legally operative incidental take permits for habitat conservation plans (HCPs) issued under section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended (Act), in which bull trout is a covered species on or before the publication of this final rule; (2) waters within or adjacent to Tribal lands subject to certain commitments to conserve bull trout or a conservation program that provides aquatic resource protection and restoration through collaborative efforts, and where the Tribes indicated that inclusion would impair their relationship with the Service; or (3) waters where impacts to national security have been identified (75 FR 63898). Excluded areas are approximately 10 percent of the stream/shoreline miles and 4 percent of the lakes and reservoir acreage of designated critical habitat. Each excluded area is identified in the relevant Critical Habitat Unit (CHU) text, as identified in paragraphs (e)(8) through (e)(41) of the final rule (see Tables 3 and 4 for the list of excluded areas). The exclusion of waterbodies from designated critical habitat does not negate or diminish their importance for bull trout conservation. Because exclusions reflect the often complex pattern of land ownership, designated critical habitat is often fragmented and interspersed with excluded stream segments.

Table 3. Stream/shoreline distance excluded from bull trout critical habitat based on tribal ownership or other plan.

Ownership and/or Plan	Kilometers	Miles
Lewis River Hydro Conservation Easements	7.0	4.3
DOD – Dabob Bay Naval	23.9	14.8
HCP – Cedar River (City of Seattle)	25.8	16.0
HCP – Washington Forest Practices Lands	1,608.30	999.4
HCP – Green Diamond (Simpson)	104.2	64.7
HCP – Plum Creek Central Cascades (WA)	15.8	9.8
HCP – Plum Creek Native Fish (MT)	181.6	112.8
HCP–Stimson	7.7	4.8
HCP – WDNR Lands	230.9	149.5
Tribal – Blackfeet	82.1	51.0
Tribal – Hoh	4.0	2.5
Tribal – Jamestown S'Klallam	2.0	1.2
Tribal – Lower Elwha	4.6	2.8
Tribal – Lummi	56.7	35.3
Tribal – Muckleshoot	9.3	5.8
Tribal – Nooksack	8.3	5.1
Tribal – Puyallup	33.0	20.5
Tribal – Quileute	4.0	2.5
Tribal – Quinault	153.7	95.5
Tribal – Skokomish	26.2	16.3
Tribal – Stillaguamish	1.8	1.1
Tribal – Swinomish	45.2	28.1
Tribal – Tulalip	27.8	17.3
Tribal – Umatilla	62.6	38.9
Tribal – Warm Springs	260.5	161.9
Tribal – Yakama	107.9	67.1
Total	3,094.9	1,923.1

Table 4. Lake/Reservoir area excluded from bull trout critical habitat based on tribal ownership or other plan.

Ownership and/or Plan	Hectares	Acres
HCP – Cedar River (City of Seattle)	796.5	1,968.2
HCP – Washington Forest Practices Lands	5,689.1	14,058.1
HCP – Plum Creek Native Fish	32.2	79.7
Tribal – Blackfeet	886.1	2,189.5
Tribal – Warm Springs	445.3	1,100.4
Total	7,849.3	19,395.8

4.2 Primary Constituent Elements for Bull Trout Critical Habitat

Within designated critical habitat areas, the PCEs for bull trout critical habitat are those physical and biological features that are essential for the primary biological needs of foraging, reproducing, rearing of young, dispersal, genetic exchange, or sheltering. Based on our current knowledge of the life history, biology, and ecology of the bull trout and the characteristics of the habitat necessary to sustain its essential life-history functions, we have determined that the following PCEs are essential for the conservation of bull trout.

1. Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.
2. Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.
3. An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.
4. Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.
5. Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.
6. In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout will likely vary from system to system.
7. A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.
8. Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

9. Sufficiently low levels of occurrence of non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.

Only PCEs 2, 3, 4, 5, and 8 apply to marine nearshore waters identified as critical habitat. Lakes and reservoirs within the CHUs can contain most of the physical or biological features necessary to support bull trout, with the exception of those associated with PCEs 1 and 6. Additionally, PCE 6 does not apply to FMO habitat designated as critical habitat. Although PCE 9 applies to both the freshwater and marine environments, currently no non-native fish species are of concern in the marine environment, though this could change in the future.

The Service evaluates activities that cause adverse effects to critical habitat to determine if they are likely to "destroy or adversely modify" critical habitat to an extent that it no longer serves the intended conservation role for the species nor retains the function of those PCEs that relate to the ability of the area to support the species. Activities that may destroy or adversely modify critical habitat are those that alter the PCEs to such an extent that the conservation value of critical habitat is appreciably reduced (75 FR 63898; USFWS 2004d, Vol. 1. pp. 140-193, Vol. 2. pp. 69-114).

4.3 Conservation Role and Description of Bull Trout Critical Habitat

The conservation role of bull trout critical habitat is to support viable core area populations (75, FR 63898). Core areas reflect the metapopulation structure of bull trout and approximate relatively discrete units for the purposes of recovery planning and risk analyses. Critical habitat units generally encompass one or more core areas and may include FMO areas, outside of core areas, that are important to the survival and recovery of bull trout. The Service designated 32 CHUs and 78 associated subunits within the geographical area occupied by bull trout under the 2010 rule. Twenty-nine of the CHUs contain all of the physical or biological features identified in this final rule and support multiple life-history requirements. Three of the mainstem river units in the Columbia and Snake River basins contain most of the physical or biological features necessary to support the bull trout's particular use of that habitat.

The primary function of individual CHUs and subunits is to maintain and support core areas. These core areas, in turn, have multiple functions and characteristics, which include: (1) contain bull trout populations with the demographic characteristics needed to ensure their persistence and contain the habitat needed to sustain those characteristics (Rieman and McIntyre 1993, p. 19); (2) provide for persistence of strong local populations and, in part, provide habitat conditions that encourage movement of migratory fish (MBTSG 1998, pp. 48-49; Rieman and McIntyre 1993, pp. 22-23); (3) cover an area large enough to incorporate genetic and phenotypic diversity, but small enough to ensure connectivity between populations (Hard 1995, pp. 314-315; Healey and Prince 1995, p. 182; MBTSG 1998, pp. 48-49; Rieman and McIntyre 1993, pp. 22-23); and 4) represent the full historic range of the species to preserve both genetic and phenotypic adaptations (Hard 1995, pp. 321-322; MBTSG 1998, pp. 13-16; Rieman and Allendorf 2001, p. 763; Rieman and McIntyre 1993, p. 23).

To determine what should be designated as critical habitat for bull trout, the Service identified specific areas that contain the physical and biological features essential to bull trout conservation, considering distribution, abundance, trend, and connectivity needs. The objective was to ensure the areas designated as critical habitat would effectively serve the following recovery goals:

- Conserve opportunity for diverse life-history expression
- Conserve opportunity for genetic diversity
- Ensure bull trout are distributed across representative habitats
- Ensure sufficient connectivity among populations
- Ensure sufficient habitat to support population viability (e.g. abundance, trends)
- Consider threats to the species
- Ensure sufficient redundancy to conserve population units

The Bull Trout Final Critical Habitat Justification document (USFWS 2010) provides the rationale for the designation of areas to meet the conservation needs of bull trout, including the uniqueness of some CHUs. For example, the Olympic Peninsula and Puget Sound CHUs are the only CHUs that support amphidromous[2] bull trout and are unique to the Coastal-Puget Sound population segment. These two CHUs contain marine nearshore and freshwater habitats, outside of core areas, that are used by bull trout that seasonally migrate from one or more core areas. These habitats contain physical and biological features that are critical to adult and subadult foraging, overwintering, and migration, and are essential for the conservation of this unique life history.

4.3.1 *Activities that May Affect PCEs*

The final rule (75 FR 63898) states, "A variety of ongoing or proposed activities that disturb or remove primary constituent elements may adversely affect, though not necessarily 'adversely modify' bull trout critical habitat as that term is used in section 7 consultations." Actions that may destroy or impact critical habitat could occur within the waterbody and/or on lands adjacent to or upstream of waterbodies designated as critical habitat. Activities that have been identified as directly and/or indirectly affecting bull trout critical habitat PCEs include but are not limited to the following: mining, agriculture, grazing, water use, flood control, bank stabilization and other instream construction work, recreation, transportation development, road maintenance, timber harvest, dams, and the introductions of nonnative invasive species. These activities may affect bull trout critical habitat by altering water chemistry, creating instream barriers (both permanent and temporary), increasing water temperature, reducing the food base, and precluding natural stream and hydrologic functions.

4.4 Current Critical Habitat Condition Rangewide

The condition of bull trout critical habitat varies from good to poor across its range. There is widespread agreement in the scientific literature that many factors related to human activities have impacted bull trout and their habitat, and continue to do so. Among the many factors that contribute to degraded PCEs, the following are particularly significant and have resulted in a legacy of degraded habitat conditions:

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[2] Amphidromous species leave the marine environment and return seasonally to fresh water as subadults, sometimes for several years, before returning to spawn (Brenkman and Corbett, 2005, p. 1075).

(1) Fragmentation and isolation of local populations due to the proliferation of dams and water diversions that have eliminated habitat, altered water flow and temperature regimes, and impeded migratory movements (Dunham and Rieman 1999, p. 652; Rieman and McIntyre 1993, p. 7);
(2) Degradation of spawning and rearing habitat and upper watershed areas, particularly alterations in sedimentation rates and water temperature, resulting from forest and rangeland practices and intensive development of roads (Fraley and Shepard 1989, p. 141; MBTSG 1998, pp. ii - v, 20-45);
(3) The introduction and spread of nonnative fish species, particularly brook trout and lake trout, as a result of fish stocking and degraded habitat conditions, which compete with bull trout for limited resources and, in the case of brook trout, hybridize with bull trout (Leary et al. 1993, p. 857; Rieman et al. 2006, pp. 73-76);
(4) In the Coastal-Puget Sound region where amphidromous bull trout occur, degradation of mainstem river FMO habitat, and the degradation and loss of marine nearshore foraging and migration habitat due to urban and residential development; and
(5) Degradation of FMO habitat resulting from reduced prey base, roads, agriculture, development, and dams.

Since the revised critical habitat designation became effective on November 17, 2010, few projects and natural events have occurred that have affected the condition of critical habitat. Thus at the rangewide scale, the current baseline condition of critical habitat is fundamentally the same as it was at the time of designation. No Section 7 consultations on projects have concluded that adverse modification of critical habitat was likely, and no large natural events have changed the baseline condition of any units. Likewise, the ongoing effects of climate change are modifying the condition of critical habitat, but the short period of time since designation suggests that climate-related changes are likely negligible.

5 ENVIRONMENTAL BASELINE OF BULL TROUT CRITICAL HABITAT

The action area is part of the Yakima River Basin critical habitat unit (Unit 11), as designated by the Service's October 18, 2010, final rule (75 FR 63898). For context, we first provide a general characterization of the overall status of the entire critical habitat unit and follow with a detailed description of the critical habitat in the action area and the factors affecting critical habitat in the action area.

5.1 Environmental Baseline for the Yakima CHU

The Yakima River CHU supports adfluvial, fluvial, and resident life history forms of bull trout. This CHU includes the mainstem Yakima River and tributaries from its confluence with the Columbia River upstream from the mouth of the Columbia River upstream to its headwaters at the crest of the Cascade Range. The Yakima River CHU is located on the eastern slopes of the Cascade Range in south-central Washington and encompasses the entire Yakima River basin located between the Klickitat and Wenatchee Basins. The Yakima River basin is one of the largest basins in the state of Washington; it drains southeast into the Columbia River near the town of Richland, Washington. The basin occupies most of Yakima and Kittitas Counties, about half of Benton County, and a small portion of Klickitat County. This CHU does not contain any subunits because it supports a single core area. A total of 1,177.2 km (731.5 mi) of stream habitat

and 6,285.2 ha (15,531.0 ac) of lake and reservoir surface area in this CHU are designated as critical habitat. One of the largest populations of bull trout (South Fork Tieton River population) in central Washington is located above the Tieton Dam and supports the core area. This CHU supports two potential resident local populations identified in the U.S. Fish and Service's 2008 five year review (Service 2008, p. 6).

Overall, the general habitat conditions in the Yakima CHU show a similar pattern; lower reaches of the mainstem Yakima and its tributaries are fairly degraded, likely influenced by the high degree of development, roads, forestry, agriculture, irrigation diversions, grazing, mining, and other infrastructure and land management. These reaches may also have 303(d) listed impairments of water quality, with temperature and instream flow being fairly common. In contrast, the upper reaches are generally of higher quality and have less anthropogenic impacts, although there is substantial variation across the CHU.

The following is a description of the current condition of each PCE of critical habitat in the Yakima CHU, acknowledging there is substantial variation among watersheds within the CHU.

- *PCE 1: Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.*

  Historically, the hydrologic cycle of the Basin was characterized by extensive exchange between surface waters and the shallow alluvial groundwater aquifers (Kinnison and Sceva 1963). Spring runoff (and other high flow events) spread across the floodplain, distributing cold water into side channels that percolated into and recharged the alluvial aquifer. Alluvial aquifers served as hydrologic buffers that returned water to the Yakima River as baseflow later in the season after the cessation of snowmelt runoff. Current hydrology in the Yakima core area is controlled by the Bureau of Reclamation's Yakima Basin Project, and these controlled flows deviate significantly from the natural flow regime.

  Through annual flow manipulation, the BOR Project has significantly altered the natural hydrologic system within the Yakima River Basin by: (1) significantly reducing the extent of alluvial flood plain habitats and the role of alluvial aquifers in maintaining cold water in streams; (2) altering the runoff regime; and (3) disrupting the longitudinal, vertical, and horizontal connectivity of affected river systems within the Basin. Significant flood plain encroachment also has occurred in the Basin. On average, 66 percent of five alluvial reaches evaluated have been physically disconnected (Eitemiller et al. 2000). In the upper Yakima Basin, an average of 60 percent of the floodplain has been lost and from 57 to 85 percent of the floodplain in the lower Yakima River has been lost (Snyder and Stanford 2001). These encroachments have eliminated or isolated large areas of side channels and sloughs.

  What little functional flood plain that remains has been, and continues to be, affected by BOR Project operations. River operations for irrigation and flood control alter the natural hydrograph by impounding high flow events. A common effect of these operations is a sharp reduction in the frequency with which high flow events recharge the alluvial flood

plain aquifer. Truncation of flood peaks by capture in reservoirs also reduces the duration, magnitude, and spatial extent of flood plain inundation. This not only alters the quantity, quality, and timing of groundwater discharge to the river but also diminishes the availability, extent, and temporal duration of off-channel habitats. These changes in the pattern of floodplain inundation also have the undesirable effect of encouraging further commercial and residential development on the flood plain. Flood plain disconnection combined with flow regulation (i.e., the inversion and truncation of the natural hydrograph) have dramatically reduced river flood plain interactions. The result has been a loss of horizontal and vertical connectivity, diminished habitat heterogeneity through the loss of off-channel habitat, and a general loss of ecosystem function. Because these alterations are concentrated in the lower watershed, this PCE illustrates the general pattern described above of degraded conditions in the lower watershed and good conditions in the upper reaches of tributaries. Considering the scale of the entire subunit, we believe the baseline condition of this PCE is "functioning at risk."

- *PCE 2: Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.*

  There are five major storage reservoirs in the basin; Keechelus, Kachess, and Cle Elum in the Yakima sub-basin, and Bumping and Rimrock in the Naches sub-basin. None of the dams forming these reservoirs provide upstream fish passage. Of the 16 identified local populations, 12 are either completely or partially isolated. These passage barriers have fragmented the bull trout metapopulation and limited migration to high quality spawning, foraging, and overwintering habitat.

  Water withdrawals from streams by irrigation diversions within the basin contribute to low flow conditions in some streams (i.e., Manastash, Taneum, Naneum, Ahtanum, and Cowiche Creeks and the Tieton River), and seasonal dewatering of others. Seven mainstem irrigation diversion dams (Easton, Town Ditch, Wapato, Sunnyside, Prosser, Yakima Tieton Irrigation District, and Horn Rapids) have contributed to altered flow regimes within the basin (Snyder and Stanford 2001). Low flows can inhibit bull trout spawning migrations and result in the stranding of juvenile bull trout in Ahtanum and Rattlesnake Creeks and Teanaway River (E. Anderson, WDFW, 2002, pers. comm.).

  The combination of anthropogenic barriers to migration and the common occurrence of barriers due to dewatering in the mainstem and tributaries lead us to consider the overall condition of this PCE to be "functioning at unacceptable risk."

- *PCE 3: An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.*

  We have no direct information regarding this PCE, but may infer its functionality through evaluating the general condition of riparian areas, water quality/quantity, and overall habitat complexity. The condition of riparian areas and habitat complexity generally

improves in the upper portions of the watershed, as the influences of development, agricultures uses, and other human management decreases. The exception may be commercial forestry, which can have locally significant effects on habitat condition and generally occurs in the mid- to upper- elevation areas in the CHU.

In most watersheds, roads parallel waterways and degrade riparian function, as well as channel dynamics and habitat complexity. Forest road location and density significantly degrade riparian conditions in some watersheds, likely to a degree that influences the food base for bull trout.

The diminished abundance of anadromous salmon is probably the most serious and persistent effect on bull trout food availability in the Yakima CHU. This factor, in combination with the effects of roads, leads us to consider this PCE as "functioning at risk."

- *PCE 4: Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.*

  Similar to PCE 3, the functionality of PCE 4 generally improves as you move up the watershed and development and land management pressures decrease. In lower portions of the Yakima CHU, many of the features or outcomes associated with development and land management (e.g., roads, residential development, agriculture, and livestock grazing) contribute to loss of wetlands and riparian areas and impair habitat complexity in aquatic environments. Roads and development impinge on stream channels, and riprap and levees designed to protect property and reduce flooding simplify habitats and alter hydrologic function, especially when large woody debris is removed or reduced in size or distribution. This in turn can alter sediment deposition patterns, large woody debris transport, and pool development. A variety of restoration activities have occurred in recent years, including reconnection of off-channel habitats, improved road maintenance, culvert replacement, road relocation, and installation of large woody debris. High variability among watersheds regarding the condition of this PCE makes it especially challenging to specify a synthetic rating for the entire CHU. Because bull trout require complexity in both FMO (lower watershed) and SR (upper watershed) habitats, we consider this PCE to be "functioning at risk," overall.

- *PCE 5: Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.*

  Throughout the Yakima Basin, over 45 streams have been listed on the 303(d) list of impaired waterbodies due to elevated temperatures. These waterbodies include most of the streams inhabited by local populations of bull trout.

Craig (1997) found that streams in the Yakima River basin with more than 20 redds had a 7-day summer mean temperature below 12 °C, and no single day with a temperature > 14.8 °C, while monitoring from the Lower Yakima and Naches rivers have shown extended river reaches with water temperatures that exceed the physiological tolerances of native salmonids (Yakima Basin Fish and Wildlife Recovery Board [YBFWRB] 2005). These data illustrate the general pattern described above of degraded conditions in the lower watershed and good conditions in the upper reaches of tributaries. Considering the scale of the entire subunit, we believe the baseline condition of this PCE is "functioning at risk."

- *PCE 6: In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout will likely vary from system to system.*

  The overall condition of substrate in spawning and rearing areas is generally good, because these areas are predominantly located in areas subject to little development or management pressures. Conditions among tributaries in the unit are, however, highly variable, and are influenced by the specific hydrologic, geologic, and other processes occurring in different watersheds. Bull trout rearing in many portions of this unit occurs in areas where extensive bank armoring and other changes associated with residential development have occurred. Substrate characteristics in these areas have likely been modified in ways that reduce survival. Considering both transient changes in substrate characteristics due to natural disturbance, and more chronic changes associated with development, we believe the overall condition of PCE 6 is "functioning at risk" in this CHU.

- *PCE 7: A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.*

  The Yakima, Cle Elum, Tieton, Bumping, and Naches rivers are manipulated to maximize winter reservoir storage and summer irrigation deliveries according to the seasonal needs of irrigators (YBFWRB 2005). These operations result in streamflows that are mostly out of phase with the life history requirements of native salmonids. Reservoir operations combined with diversions across the Yakima Basin have inverted and truncated the natural pattern of streamflow so that river systems are now spatially and temporally discordant with their surrounding watersheds. Water withdrawals from streams by irrigation diversions within the basin contribute to low flow conditions in some streams (i.e., Manastash, Taneum, Naneum, Ahtanum, and Cowiche Creeks and the Tieton River), and seasonal dewatering of others. Seven mainstem irrigation diversion dams (Easton, Town Ditch, Wapato, Sunnyside, Prosser, Yakima Tieton Irrigation District, and Horn Rapids) have contributed to altered flow regimes within the basin

(Snyder and Stanford 2001). Overall the condition of this PCE is "functioning at unacceptable risk," due primarily to hydrograph manipulations by storage reservoir operations and reductions in base flows.

- *PCE 8: Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.*

  The condition of this PCE is variable across the CHU. In spawning areas, water quality and quantity is generally good. In rearing areas, conditions are variable, with some degradation in both water quality (primarily due to increased sedimentation) and quantity. In FMO habitat in the lower portions of the CHU, numerous reaches are 303d listed for impairments due to pollutants. As described above, water withdrawals have also reduced water quantity sufficient to warrant 303d listing for low in-stream flow. Overall, PCE 8 is "functioning at risk" based on our qualitative integration of variable conditions across the entire CHU.

- *PCE 9: Sufficiently low levels of occurrence of non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.*

  A variety of non-native fish have been stocked throughout the CHU in the past for a variety of purposes including increased recreational angling opportunities. While this no longer occurs in connected waterways, several species of non-native fish are present throughout the CHU and likely have negative effects to bull trout including competition, hybridization, and predation. Brook trout are widely distributed in the unit. While we know that negative interactions are occurring with non-native fish species, we cannot quantify the magnitude of this effect. Given this uncertainty, we assume this PCE to be "functioning at risk" at the scale of the CHU.

Integrating across PCEs, the overall condition Yakima CHU is "functioning at risk," with considerable variability within and between watersheds. Spawning and rearing areas are generally in more functional condition than FMO habitat.

The following sub-sections describe the baseline condition of critical habitat at the action area scale. At this smaller scale, we can provide a more specific assessment of PCE function because we are describing conditions at a specific location rather than trying to characterize typical conditions across a broad geographic area that is highly variable.

5.2 Environmental Baseline of Critical Habitat in the Action Area

To streamline this analysis, we use a "crosswalk" (Appendix C), which shows the relationship between the PCEs of critical habitat and the MPI habitat indicators. Many of the physical, chemical, and biological features of the PCEs of critical habitat correspond to MPI habitat indicators.

As described in section 1.1 above, the Action Area for this Project includes the reach of the mainstem Teanaway River adjacent to the subject property. The role of critical habitat in the action area is primarily to provide FMO habitat functions. The Service based its expectation about the functional roles of critical habitat on both current and potential future habitat use by bull trout. Different life history stages of bull trout likely use SR habitat and FMO habitat in different ways. For example, SR habitat may be used by migratory adult bull trout not just for spawning, but also for foraging. Juvenile and sub-adult bull trout may also use FMO habitat for rearing. Movement of these life stages to downstream areas can result from volitional emigration or their inability to remain in their natal reach due to peak flows when refugia are limited (see Downs et al. 2006).

Using the terminology of the MPI, we consider all 9 PCEs to be "functioning at risk" across the narrow action area affected by this Project (Table 5). This is largely a reflection of lack of specific information about many PCEs at the site scale.

Table 5. Status of Critical Habitat in the Action Area

PCE	Functioning Appropriately	Functioning at Risk	Functioning at Unacceptable Risk
PCE 1 - Springs, Seeps, Groundwater		X	
PCE 2- Migratory Corridors		X	
PCE 3 - Abundant Food Base		X	
PCE 4 - Complex Habitats		X	
PCE 5 - Temperature		X	
PCE 6 - Substrate		X	
PCE - 7 Hydrograph		X	
PCE 8 -Water Quality/ Quantity		X	
PCE 9 - Nonnative Species		X	

5.2.1 *Factors Affecting Critical Habitat in the Action Area*

Many of the same factors described in the Environmental Baseline, sections 3.1.2, 3.2.2, and 3.3.3 above, likely affect the condition and functionality of critical habitat in the action area in a similar manner. At the action area scale, no specific information is available about how factors are affecting food base (PCE 3), or how recent restoration activities to improve opportunities for fish passage at culverts and diversion dams have affected the distribution and abundance of non-native species, especially brook trout.

6 EFFECTS OF THE ACTION ON BULL TROUT AND BULL TROUT CRITICAL HABITAT

The Service's section 7 regulations define "effects of the action" as "the direct and indirect effects of an action on the species together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline" (50 C.F.R. 402.02). "Indirect effects" are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur.

As we described in the Environmental Baseline section above, the MPI provides the framework the Service uses to assess potential Project effects (USFWS 1999). This format, adapted from the 1996 National Marine Fisheries Service format of a similar name, includes a decision matrix with pathways and indicators (MPI) designed to describe a baseline of population and habitat conditions and effects of the proposed action on these conditions. Baseline conditions are described on a relative scale of functionality for each indicator. We then evaluate project effects on each indicator in the context of the environmental baseline in the action area. We consider proximity, distribution, timing (duration, frequency), type, intensity, and severity of effects in order to evaluate the degree of effect resulting from project implementation (USDI and USDC 1998, pp. 4-22 to 4-24). The Service typically expresses degree of effect in terms of impacts to individual fish and fish populations and deviations of habitat indicators in the MPI from their baseline condition. This entire process is described in the *Analytical Process for Developing Biological Assessments for Federal Actions Affecting Fish within the Northwest Forest Plan Area* (USDA et al. 2004), a document produced through interagency cooperation between the Service, the National Marine Fisheries Service, the Bureau of Land Management, and the U.S. Forest Service. We apply this analytical process to our analysis of the effects of this proposed Project.

In an effort to streamline our analysis of Project effects, we consider simultaneously effects on the bull trout, as well as effects on designated critical habitat for the bull trout. We do this in the context of the MPI by first considering direct effects on bull trout population indicators, and second, by considering effects on habitat indicators. We then rely on the Crosswalk (Appendix C) to translate Project effects on indicators into a summary of effects on PCEs of critical habitat.

To begin our analysis of effects, we typically deconstruct projects into separate elements that trigger different impact mechanisms. We have characterized this Project as having four elements, all of which may result in adverse effects to bull trout (see Project Description above and in the BA for details). The Service used the Project elements defined in the Project Description above to structure our analyses of direct effects to bull trout and indirect effects to habitat conditions. For ease of reference, we use the following labels for the four primary Project elements:

1. Installation of Temporary Erosion and Sediment Control Measures
2. Channel Reconfiguration and Overflow Bench and Spoil Pile Grading
3. Installation of Rock Vanes and Large Woody Debris, and
4. Planting.

To describe and analyze Project effects in a logical way, we identified the following underlying premises:

1. Project elements trigger various impact mechanisms that directly kill (lethal effect), injure, or modify the behavior of bull trout, or result in changes in habitat condition that cause indirect injury (sub-lethal effects). Sub-lethal effects can vary from transient but significant disruptions of feeding behavior that temporarily reduce physiologic condition to physical injuries that reduce longevity and reproductive success.
2. All adverse effects can be integrated and expressed in the common currency of changes in the numbers, distribution and reproduction of bull trout.

3. The beneficial effects of the Project will occur predominantly over the longer term, after areas disturbed during Project implementation have re-vegetated and stabilized and additional plantings have matured.
4. Individual bull trout from local populations in the Yakima core area may be affected by the Project. Bull trout from other core areas may possibly be exposed to Project effects, but we believe that the likelihood of this is sufficiently low to be considered discountable.

Based on these premises, our effect analysis consists of two major components:

1. Evaluate the potential for direct injury or mortality of individual bull trout, and
2. Evaluate the potential for effects on habitat indicators to result in indirect adverse effects.

We integrate both components to determine their combined influence on the numbers, distribution and reproduction of bull trout populations exposed to effects of the action. Evaluating effects at the individual level relative to components 1 and 2 requires several sub-steps:

a. Determine which project elements and impact mechanisms are likely to result in adverse effects,
b. Identify the life stages most likely exposed to those effects.
c. Estimate the number of individuals in these life stages that will be exposed to project effects based on the intersection between the timing of element effects and the seasonal timing of habitat use by different life stages. This typically involves estimating the total number of individuals present in the vicinity at the time project activities begin and the number of individuals likely to pass through the affected area during the anticipated period of effects and,
d. Estimate the relative severity of effects resulting from exposure.

Determining the Project elements likely to result in adverse effects can be accomplished by qualitatively evaluating the potential effects of each element on bull trout individuals and habitat indicators (Table 6). Although Table 6 resembles the "checklist" in the Matrix of Pathways and Indicators, we are not referring here to watershed-scale effects on indicators. Rather, we simply borrow the familiar MPI format to structure our qualitative ratings of the effects of Project elements on bull trout individuals at the action area scale. Identifying life stages likely to be exposed can usually be based on relatively good information about spatial and temporal patterns of habitat use. Estimating numbers of individuals exposed and the relative severity of effects requires many assumptions. The most basic assumption is that average conditions in the past can be used as an index of conditions during Project implementation. Numerous additional assumptions about population size, age structure, migration timing, reproductive rate and other features contribute to high levels of uncertainty surrounding these estimates. The Service attempts to be as transparent as possible about these sources of uncertainty.

Table 6. Relative effects of Project elements on bull trout and habitat indicators.

Direct effects and Indirect impact mechanisms (habitat indicators)	Project Elements			
	Erosion and Sediment Control	Channel Reconfiguration and Grading	Rock Vane and LWD Installation	Planting
Direct injury	---	-	-	-
Temperature			-	+
Sediment/turbidity	--	-	-	-
Chemical contaminants and nutrients	-	-	--	-
Physical barriers	-			
Embeddedness	--	--	---	-
Large Wood			+	+
Pool frequency and quality		+	+	
Large pools				
Off-channel habitat		---	---	
Refugia				
Width:depth ratio		+	+	
Streambank condition	-	--	--	+
Floodplain connectivity	-	--	--	
Peak and base flow				
Drainage network				
Road density and location				
Riparian reserves	-	-	-	+
Disturbance History		--	--	
Disturbance regime		--	--	

Minus signs indicate level of negative impact. One minus sign indicates a negative impact that is insignificant or discountable. Two minus signs indicates a negative impact that has the potential to cause an adverse effect to a listed species that can be reliably avoided by proper implementation of conservation measures. Three minus signs indicate a high likelihood of causing an adverse effect in all or a proportion of individuals exposed to this impact. A blank indicates an indicator is unlikely to be directly or indirectly affected by a project element because there are no impact mechanisms that link the project element to an indicator. Plus signs denote beneficial effects.

6.1 Direct Effects

The Project elements with the greatest likelihood of contributing to direct injury or mortality of bull trout are installation of temporary erosion and sediment control measures, channel reconfiguration and overflow bench grading, and installation of rock vanes and woody debris. The impact mechanisms that could lead to direct injury or mortality include mechanical and physiologic injury resulting from placement of cofferdams, equipment operation, fish removal, and stranding, and exposure to turbidity plumes. Minimization measures and conservation

measures included in the Project should be effective at minimizing injury and mortality from these mechanisms. However, despite these efforts, injury and mortality will likely occur and what follows is the Service's attempt to estimate the magnitude of these effects by Project element.

The Service believes there are four impact mechanisms associated with these Project elements that can lead to direct injury or mortality of bull trout: (1) mechanical injury resulting from compaction of interstitial spaces in the substrate of the river due to cofferdam construction and operation of heavy equipment, (2) abrasion, minor trauma, and physiologic stress associated with fish capture and relocation, (3) stranding in dewatered work areas, and (4) exposure to turbidity plumes.

For all of these impact mechanisms, the location and seasonal timing of construction suggest that adult, sub-adult, and juvenile bull trout will be the life stages likely to be affected. Because no bull trout spawning has been reported in the area of the Teanaway River where the Project will occur, the Service does not expect redds to be present in the action area. Few, if any, rearing juveniles are expected to be exposed based on the assumptions that juveniles predominantly rear in tributaries near spawning areas, which are far removed from the action area, and juveniles typically do not emigrate to the mainstem Teanaway River until reaching sub-adult size (about 150 mm or 6 inches).

6.1.1. *Mechanical injury from substrate compaction, capture and relocation, or stranding.* Bull trout are strongly substrate oriented and all life stages often respond to disturbance by hiding in interstitial spaces in the substrate. This behavior can contribute to injury and mortality from crushing if heavy equipment compacts or collapses interstitial spaces. Cofferdam construction has the greatest potential to result in this effect.

Estimating the number of individual bull trout in each life stage likely to be exposed to these activities requires an estimate of the density of each life stage in the action area. We believe that the likelihood of mechanical injury to adult bull trout is discountable, because large adult fish are mobile enough to avoid this impact, or they can easily be detected and herded out of the area without capture and handling. To estimate the numbers of juvenile and sub-adult bull trout likely to be affected, we believe the best available information regarding the density of these life stages is based on surveys conducted in spawning habitats across Washington during the development of a protocol to detect bull trout presence. These surveys revealed a statewide average density of bull trout juveniles and sub-adults in spawning areas of 0.058 bull trout per 100 square meters of stream surface area (range of 0.001 to 0.43 fish per $100m^2$; Thurow et al. 2004, pp. 15 and 53). Because coffer dam construction will occur along approximately 350 feet (107 meters) of the proposed Project, adverse effects due to substrate compaction may occur for that distance. Applying an estimated width of affected streambed of 5 meters along the entire 107-meter length of the coffer dam area yields an estimate of total stream area potentially affected of 535 meters squared. The number of bull trout juveniles and sub-adults potentially exposed to elevated suspended sediment levels can then be estimated as: $535\ m^2 * 0.058$ bull trout/$100\ m^2 \approx 1$ bull trout (Table 7).

Estimating the relative severity of effects resulting from exposure to mechanical injury is largely a matter of professional judgment. Bull trout in the adult and sub-adult life stages are highly mobile and therefore not particularly susceptible to mechanical injury. We believe the single juvenile or sub-adult bull trout potentially exposed to mechanical injury, capture and relocation, or stranding from this element is most likely to experience sub-lethal effects (Table 7).

6.1.2 *Turbidity*. We think adverse direct effects to bull trout may occur in the Teanaway River adjacent to and downstream of construction due to exposure to increased turbidity and sedimentation. Installation and removal of temporary sediment control, channel excavation and grading and material installation Project elements would be the primary sources of sediment mobilization responsible for this effect.

Elevated turbidity or suspended sediment concentrations can have adverse direct effects on exposed individuals by altering behavior and causing physiologic stress. Although no specific data are available for bull trout, responses observed in other stream salmonids are likely also to apply to bull trout. Individual fish may avoid high concentrations of suspended sediments altogether (Hicks et al. 1991). Even small elevations in suspended sediment may reduce feeding efficiency and growth rates of some salmonids. At lower concentrations of suspended sediment fish may decrease feeding and at higher concentrations may cease feeding completely (Sigler et al. 1984). In addition, patterns of social behavior may be altered by suspended sediment (Berg and Northcote 1985). Depending upon the concentration and duration of exposure, sediment can directly affect physiological condition and normal behavior (Newcombe and MacDonald 1991; Waters 1995; Newcombe and Jensen 1996; Bash et al. 2001).

Newcombe and Jensen (1996, pgs. 694 - 700) used empirical data from the most sensitive individuals within species groups, including salmonids, to develop a model to estimate a severity-of-ill-effect rating from suspended sediment. The effects characterized by Newcombe and Jensen (1996, pgs. 700 - 705) include a broad range of physiological and behavioral responses to suspended sediment and varies as a function of suspended sediment concentration and duration of exposure. The Service uses this model to evaluate the effects of sediment inputs from proposed projects. Application of this model is hampered by uncertainty surrounding the concentrations and duration of sediment releases from different types of project activities.

A recently completed compilation of turbidity effects associated with different management activities did not include any well-monitored examples with the suite of project elements of this Project. Consequently, we provide the following rationale to support our professional judgment that adverse effects may occur. The Service believes that, like other salmonids, adult bull trout, are more sensitive to increases in turbidity than juvenile salmonids. Using the suspended sediment concentration and duration of exposure criteria of Newcombe and Jensen (1996), adverse effects can occur when adults are exposed to an elevation above background levels of about 1,000 micrograms per liter (mg/L) of suspended solids for a period of 3 hours. We expect that the duration of increased sediment pulses associated with Project activities are likely to be on the order of 3 hours. We also expect that elevation levels above background will be relatively high, given that fall low flow is typically the period when background turbidity levels are low in the Teanaway. Finally, we expect the conservation measures to be relatively effective at limiting sediment yield from the proposed Project to relatively short pulses.

Suspended sediment concentrations in plumes produced during cofferdam placement and removal, bank excavation, and material placement are difficult to predict. Based on culvert removal projects where empirical measurements of suspended sedimentation were available (Foltz et al. 2008, pgs. 334 -339), the Service expects that the proposed activities could produce peak concentrations that elevate suspended sediment concentrations by greater than 1,000 mg/L, with a typical duration of hours. Concentrations and exposure durations in this range are likely to result in sub-lethal effects on juvenile, sub-adult and adult bull trout exposed to these plumes (Newcombe and Jensen 1996, pgs. 700 - 703). The Service's expectation is approximate because the amount of material to be moved in the proposed Project is considerably larger than in the culvert-removal projects monitored by Foltz et al. (2008), and the flow rate of the Teanaway River is also appreciably larger. We believe it is reasonable to expect that the combination of effective conservation measures included in this Project, site-specific substrate characteristics, and the dilution effect of higher streamflow will lead to sediment concentrations and turbidity levels similar to or less than those measured by Foltz et al. (2008).

The Service also believes that turbidity plumes resulting from this Project element are likely to drop to levels that will not result in adverse effects to bull trout of any life stage at distances greater than 180 meters (600 feet) downstream (Foltz et al. 2008, pg. 335; Newcombe and Jensen 1996, pg. 699). We expect at least two plumes to occur (cofferdam placement and cofferdam removal) and that the resulting sediment plumes are likely to occupy only a portion of the water column within about 5 meters of the streambank. This will provide appreciable opportunity for bull trout to avoid the plumes by moving laterally in the river. Other minor sediment pulses could occur, but our expectation is that the volume of sediment mobilized and duration of resulting plumes would result in insignificant effects on any bull trout exposed to them.

To estimate the number of bull trout adversely affected by exposure to high suspended sediment concentrations resulting from this Project element we use an approach similar to that described above for other impact mechanisms. We assume that all juvenile and sub-adult bull trout present in the area 180 m (600 feet) downstream of the source of mobilized sediment and within 5 meters of the left bank could be exposed to increased sedimentation. At an estimated density of 0.058 bull trout per 100 meters squared, we estimate that 1 juvenile or sub-adult bull trout holding or rearing downstream of the work area may be exposed (Table 7).

Adult bull trout are highly mobile and move primarily at night (Downs et al. 2006, pg. 195), when construction activities will not be occurring, and migratory movements of adult and sub-adult bull trout tend to be rapid (e.g., Muhlfeld and Marotz 2005). These factors will likely allow most adult bull trout and some sub-adult bull trout to either avoid sediment plumes, or to leave work areas affected by sediment plumes with negligible physiologic or competitive costs.

Based on our previous assumptions about sediment concentrations, duration, and total number of plumes generated during implementation of this Project element, the Service expects that all bull trout exposed to these plumes will experience sub-lethal adverse effects. This expectation incorporates consideration of the number (2), duration (multiple hours per pulse), and intensity (greater than 1,000 mg/L) of sediment plumes to which these individuals will likely be exposed throughout implementation of these Project elements.

For most bull trout exposed to sediment pulses, the Service expects that the severity of sub-lethal effects will be sufficiently mild that the likelihood of survival and reproduction of exposed individuals will not be reduced appreciably (e.g., diminished physiologic condition resulting from impaired foraging behavior and depletion of energy reserves can be rapidly alleviated after exposure to Project effects). We do not expect the combined sub-lethal effects of exposure to increased sedimentation and exposure to other impact mechanisms to result in lethal consequences, only increased severity of sub-lethal adverse effects.

Table 7. Summary of direct adverse effect estimates stratified by impact mechanism, life stage, and severity of effect. See text for derivation of these estimates.

			Severity of Estimated Effect		
Impact Mechanisms	Exposure context and life stage	Estimated number exposed	Exposed but not adversely affected	Sub-lethal effects	Lethal effects
Exposure to substrate compaction	Adults	0	0	0	0
	Sub-adults and juveniles	1	0	1	0
Exposure to elevated suspended sediment	Adults	0	0	0	0
	Sub-adults and juveniles	1	0	1	0
	Total	2		2	

6.2 Effects to Habitat Indicators

The following sub-sections address indirect effects to bull trout from Project implementation. We discuss both negative and beneficial Project effects to habitat indicators in the MPI (see Table 6 for a qualitative summary). The BA for the Project provided an analysis of the likely effects of the Project on habitat indicators. With few modifications, mostly regarding the likely magnitude of effects, the Service agrees with the findings in the BA.

We agree that the Project does not include elements that are likely to affect the following habitat indicators; "large pools," "refugia," "peak and base flows," "drainage network," and "road density and location" (Table 6). These indicators will not be discussed further in this BO.

6.2.1 *Stream Temperature*

The baseline condition of this indicator in the Teanaway watershed is "functioning at risk." Effects on stream shading from all Project elements will be insignificant at this relatively wide section of the Teanaway River. No trees or shrubs present in the construction area will be removed. Revegetation of the Project area along with additional riparian plantings, may have minor beneficial effects on microclimate, but we expect these effects to be insignificant at both the reach and watershed scales.

6.2.2 *Sediment*

The sediment and substrate embeddedness indicators are "functioning at risk" in the Project area. We agree that each of the Project elements has the potential to affect these indicators (Table 6),

and that channel excavation and overflow bench grading, installation of rock vanes and large woody debris and the removal of the cofferdams have the potential for contributing the greatest amount of sediment to the stream network. As discussed above in regard to direct effects of sedimentation and turbidity on bull trout, these Project elements will result in periods of fine sediment mobilization in the mainstem Teanaway River during Project construction and, to a much lesser degree, during post-Project precipitation and high-flow events. The Project will mobilize existing fine sediment in the riverbed during cofferdam placement and other Project activities will mobilize bank sediments.

We expect these sedimentation pulses will have a short-term negative effect on the sediment indicator within the action area. We also expect, based on site conditions, that the Project can be constructed in compliance with water quality standards, and that the total volume of sediment mobilized will be sufficiently small that when it has settled, it will have insignificant effects on patterns of bull trout habitat use at the site scale.

Post-construction sediment releases from the work area are likely to be similar to or less than the existing condition. The current streambank in this area is oversteepened and rapidly eroding and likely contributes relatively high amounts of sediment during precipitation and high flow events. The new armored embankment will likely produce similar levels of sedimentation during the first year post-construction, but after disturbed areas have stabilized, and plantings become established, the Project area will likely contribute appreciably less material of all particle sizes.

6.2.3 *Substrate Embeddedness*

The mainstem Teanaway River is "properly functioning" for substrate embeddedness, with cobbles being the dominant substrate and fine sediment (< 2.0 mm) making up only 7 to 8 percent of the substrate. The volume of sediment released is not expected to have significant effects on embeddedness at the site scale, given the large substrate particle size and low starting level of embeddedness.

6.2.4 *Chemical Contaminants and Nutrients*

The installation and removal of temporary sediment control, channel reconfiguration and overflow bench grading, and installation of rock vanes and large woody debris Project elements include extensive excavation using hydraulic equipment near, but not in, the wetted channel of the Teanaway River. This type of work carries a risk of accidental contamination of surface water due to leaks or spills of hydraulic fluid or fuel. We have found that regular maintenance and daily inspection of equipment typically reduces the risk of accidental contamination to discountable levels. We expect that the SPCC plan will be effective at both preventing spills and expediting appropriate responses if a spill or leak occurs.

6.2.5 *Physical Barriers or Habitat Access*

The baseline condition of this indicator is "properly functioning." During construction, temporary cofferdams used to isolate work areas could be in place for up to 4 weeks. These cofferdams could possibly limit access to shallow water habitats along the river margins that may be important foraging areas for juvenile and sub-adult bull trout. Access to these areas will be restored when construction is completed. Because the current shallow water habitat in the Project area lacks cover of any type, and the gradient in the Project area leads to relatively high-

energy flow, we expect that current shallow water habitat in the area does not provide much habitat value for any life stage of bull trout. Consequently, temporary limitations on access to this habitat are unlikely to adversely affect any bull trout.

Cofferdams will be used to isolate work areas along the left bank, directing the entire flow of the Teanaway River through an existing channel. We do not expect these cofferdams and Project-related disturbance to block movements of bull trout or anadromous salmonids through the Project area.

6.2.6 *Large Woody Debris*
The primary effect of the Project on this habitat indicator may be slightly positive. The new bank stabilization structures will include large wood integrated into the structures, live stakes on native plants inserted into gaps, and a planting on the overflow bench and along the riverbank. These features will increase large wood in the short term, and may contribute to increased large wood recruitment in the future. Due to the limited spatial extent of the Project, these beneficial effects will contribute only a slight improvement to this indicator, which is currently "functioning at risk."

6.2.7 *Pool Frequency and Quality*
Sediment releases during construction are not expected to be large enough to affect the number and quality of pools in the Project area. Although sedimentation may have a slightly negative effect on the pool quality at the reach scale, at the watershed scale the effect will be insignificant.

Placement of large wood, including root wads protruding into the channel, may contribute to pool formation in the Project reach. This will improve habitat complexity, and increase habitat quality for all life stages of bull trout using the Project area. Over time, if the protruding rootwads accumulate additional woody debris, the size of resulting scour pools increases, and planting contribute increased cover, habitat quality benefits to bull trout will increase. Due to the limited size of the Project, these beneficial effects on habitat complexity are unlikely to result in appreciable improvements in the numbers or reproduction of bull trout.

6.2.8 *Off-channel Habitat*
By stabilizing the streambank, the Project will truncate natural channel migration processes in this reach of the Teanaway River. Interrupting this process severely limits the potential for formation of new off-channel habitat in the Project area. The Project does not, however, disconnect any off-channel habitat that has been wetted in the recent past. Eliminating the potential for future development of a habitat feature that is considered a limiting factor could result in adverse effects to bull trout. The mechanisms underlying these adverse effects include (1) reduced availability of prey that would be present in higher numbers if they had access to off-channel habitats that improve survivorship, and (2) direct benefits to survivorship of juvenile and sub-adult life stages of bull trout provided by access to off-channel refugia, particularly during high flows. Rearing juveniles and sub-adults, which are the life stages most likely to benefit from access to off-channel habitat, would be the most likely to experience adverse effects.

We believe it is inappropriate to estimate the number of juvenile and sub-adult bull trout likely to be adversely affected by this indirect effect to off-channel habitat availability. Such an estimate

would require multiple assumptions about multiple factors that we do not have adequate information to address, such as the likelihood of off-channel habitat formation, lifespan of the proposed structures, and future bull trout density in this area. Although we cannot quantitatively estimate the number of bull trout affected, our qualitative sense is that the amount of off-channel habitat precluded by this Project is unlikely to be sufficient to influence bull trout abundance or productivity at the local population scale. However, this Project is one of many bank stabilization projects in the Teanaway watershed. We believe these projects have collectively reduced availability of off-channel habitat at the watershed scale to a degree that is contributing to persistently low abundance and productivity of bull trout in the Yakima Core Area.

6.2.9 *Width to Depth Ratio*

The Project will have a minor positive effect on the width to depth ratio in the Teanaway River. Installation of large wood pieces with rootwads will likely lead to some scour pool formation that slightly improves this indicator at the site scale. These benefits are likely to limited in scope to result in any change in bull trout population dynamics.

6.2.10 *Streambank Condition*

Existing stream banks in the Project area are highly modified and unstable. During construction, the Project will result in disturbance of much of the left streambank along about 750 feet of the Teanaway River. Installation of bank stabilization features will not result in the removal of any riparian trees or shrubs. Re-vegetation along the bank, overflow bench and additional planting areas will more than replace the low vegetation disturbed during Project construction.

The Project will replace a destabilized, over-steepened, and eroding alluvial bank with an artificially over-stabilized bank, armored with large wood and rock vanes. Neither of these streambank types is typical of or appropriate for this site. The over-stabilized bank will be highly resistant to the natural erosion typical of an alluvial system like the Teanaway River. The proposed over-stabilization of the bank will deprive the system of sediment in all particle size classes, including spawning gravel that could be used by both bull trout and anadromous species that provide prey for bull trout. Prevention of bank erosion is likely to lead to increased armoring of the entire channel by cobble large enough to remain in place during high flows. Lack of recruitment of sediments in smaller size classes will lead to a simplified substrate profile, reduced habitat complexity, and reduced productivity of the aquatic community. As described above for "off-channel habitat", over-stabilizing this bank will also limit channel migration through time, interrupting a process that is essential to the creation and maintenance of habitat complexity in an alluvial system. By making this streambank more stable than is appropriate for this site, the proposed Project will likely contribute to long term simplification of streambank conditions, even though it will temporarily increase complexity at the site scale at the time of installation.

We believe that the Project will have a long-term negative effect on streambank condition in the Project area. We also believe that the benefits of increased complexity provided by large wood are likely to be short lived, relative to the negative impacts of over-stabilization, which are likely to persist into the foreseeable future.

6.2.11 *Floodplain Connectivity*
We expect the Project to generally have negative effects on this indicator, primarily due to prevention of channel migration. As described above, over stabilization of the streambank interrupts the process of bank erosion typical of an alluvial river, and disruption of this key disturbance process, will likely lead to simplification of habitat conditions over the long term. This simplification will in turn reduce productivity of bull trout populations exposed to these conditions.

6.2.12 *Riparian Reserves*
The Project will have both slightly negative and slightly positive effect on this indicator. Construction will result in the temporary loss of some riparian vegetation until the successful re-vegetation of the area. Design features of the proposed Project, such as the overflow bench and inclusion of live stakes in gaps in the structures, and additional riparian planting areas, should result in improvements in riparian conditions relative to the existing condition. The temporary removal of relatively little riparian vegetation suggests that short-term effects of the Project on riparian function will result in discountable effects to bull trout exposed to these conditions. Over the long term, however, the proposed Project will help to increase riparian habitat functions through the establishment of a tree and shrub component that is currently lacking in the Project area. Long term improvement of the diverse suite of functions provided by riparian areas is likely to contribute to beneficial effects to bull trout.

6.2.13 *Disturbance History*
The Project will have small negative effects on this indicator. Construction activities will contribute further to the ongoing progression of human disturbance in the Teanaway watershed. While this individual Project has insignificant effects at the watershed scale, in combination with other past activities, especially other bank stabilization projects, it contributes to maintaining a degraded habitat condition.

6.2.14 *Disturbance Regime*
We expect the Project to generally have negative effects on this indicator, primarily due to prevention of channel migration. As described above, over stabilization of the streambank interrupts the process of bank erosion typical of an alluvial river, and disruption of this key disturbance process, will likely lead to simplification of habitat conditions over the long term. This simplification will in turn reduce productivity of bull trout populations exposed to these conditions.

6.3 Responses of Bull Trout to Habitat Effects

Project implementation will have a combination of effects on habitat conditions. Adverse effects include short-term degradation of substrate conditions and more persistent interruption of fluvial processes that contribute to habitat complexity. Over-stabilization of the left streambank in the

Project area will lead to interruption of bank erosion and channel migration. Limiting these processes will likely reduce the amount and quality of off-channel habitat, reduce floodplain connectivity, and contribute to the maintenance of degraded watershed conditions. Short term benefits will include increased large woody debris and streambank complexity at the site scale. This section integrates these effects and predicts how these effects are likely to influence the numbers, distribution, and reproduction of the local bull trout populations affected.

Although we believe preventing formation and access to off-channel habitat will have the most substantive adverse effects to bull trout, we find it impossible to quantify the magnitude of this effect. Eliminating the potential for future development of a habitat feature that is considered a limiting factor will exacerbate the degraded baseline condition of the reach where the Project is located. Bull trout will be adversely affected by reduced availability of prey that would be present in higher numbers if they had access to off-channel habitats, and reduced rearing habitat capacity for juvenile and sub-adult life stages of bull trout. Local refugia provided by off-channel habitat, particularly during high flows, may improve the survivorship of rearing bull trout. Juvenile and sub-adult bull trout rearing in the Project area will not have access to as much of these refugia as they might in the absence of the Project.

We expect these adverse indirect effects to be in the form of significant impairment of feeding and sheltering behaviors that cause sub-lethal reductions in physiologic condition and growth. We expect bull trout that experience these adverse effects to experience slight reductions in survival. The scope of the Project is small, however, limiting the scope of these effects to a very small proportion of the rearing bull trout population in the Yakima Core Area. Consequently, we do not expect these adverse indirect effects to change the numbers and reproduction sufficiently to be detectable at the core-area scale. We do not expect any changes in distribution of bull trout in the core area.

We expect the Project's beneficial effects to be similarly limited by the small spatial extent and variable functional lifespan of the habitat improving components of the Project. The Project will increase streambank complexity, add large wood, and improve the condition of riparian vegetation in the Project area. The beneficial effects provided by incorporating large woody debris in the Project will likely have a slight beneficial effect on the survival and physiologic condition of juvenile and sub-adult bull trout that rear in the Project area that persists for several years. These beneficial effects will likely diminish as the large wood installed breaks down through time. Benefits of improved riparian vegetation are likely to be more durable, and may eventually contribute to recruitment of large woody debris to the river. The scope of these beneficial effects, however, is unlikely to be sufficient to change the numbers, reproduction, or distribution of bull trout in the Yakima Core Area

6.4 Integration of Direct Effects and Indirect Habitat Effects

Direct effects of all Project elements will likely result in sub-lethal adverse effects on up to two sub-adult/juvenile bull trout (Table 8). We also anticipate future adverse affects associated with indirect habitat effects, but we have no means for estimating numbers of bull trout likely to experience these effects. We qualitatively estimate that the scope of these future effects will not be large enough to influence the numbers or reproduction of bull trout in the Yakima Core area.

This estimate is based on the limited scope of the proposed Project and small number of bull trout likely to be exposed to Project effects.

Some individuals may experience more than one sub-lethal impact. The Service believes that the severity of sub-lethal impacts is low enough that if multiple impacts to single individuals occurred they would still be sub-lethal. Future indirect effects that reduce availability of off-channel habitat may reduce survival of juvenile and sub-adult bull trout exposed to these conditions. We expect all adverse effects to occur to the Teanaway local population in the Yakima Core Area. Although the local population exposed to the effects of this Project is small, the Service believes that the Project's sub-lethal impacts are too mild and limited in scope to change overall rates of survival and reproductive success of the entire local population.

Table 8: Summary of adverse Project effects to bull trout by severity of effect and life stage.

	Effect Type				
	Direct		Indirect (habitat degradation)		
Life Stage	Lethal	Sub-lethal	Lethal	Sub-lethal	**Total**
Adult	-	-	-		-
Sub-adult/juvenile	-	2	-	Unquantifiable	2
Total	-	2	-		2

6.5 Summary of Effects to Bull Trout Critical Habitat

Based on our analysis of Project effects on habitat conditions, which is presented above, the Project is most likely to have effects on PCE 4, which considers habitat complexity, and PCE 6, concerning substrate condition in rearing habitat. Regarding PCE 4, the Project is likely to affect the condition of streambanks, floodplain connectivity, riparian reserves, and the fluvial processes that lead to the formation of complex off-channel habitat. Based on information presented in the BA and our analysis of the scope and severity of Project effects on streambank condition, riparian reserve function, and processes that produce off-channel habitat, this Project will reduce habitat complexity on a small proportion of stream length (about 750 feet), on the left bank of the Teanaway River. The effect of this Project on geomorphic processes is likely to extend beyond the footprint of the Project itself, but will nonetheless constitute far less than one percent of total stream length in critical habitat in the Yakima CHU. While Project effects may significantly reduce the capacity of particular sites to support bull trout, these effects are unlikely to affect the functional capacity of the entire stream reach where it is located.

Based on the analysis presented in the BA, we also believe that the proposed Project will have transient adverse effects on the "sediment" and "embeddedness" indicators during construction, and more persistent impacts due to interruption of fluvial processes. We believe that overstabilizing the bank will deprive the river of sediments in all size classes, and precluding channel migration that could contribute to formation of off-channel habitat. We expect these effects to persist into the foreseeable future. The spatial scope of these effects is not readily estimated, but we believe they are likely to be limited to within about 600 feet downstream of

construction (based on coarse-scale maps of past channel migration). We believe these localized adverse effect to critical habitat will have insignificant impacts on the functional capacity of the Yakima CHU to support the survival and recovery of bull trout.

Analysis of effects on PCE 9 requires information beyond that provided by the MPI. Regarding PCE 9, we do not expect the Project to influence the abundance and productivity of predators or competitors. Brook trout are present near the Project area, and the Project is likely to have a neutral effect on this PCE.

6.6 Effects of Interrelated and Interdependent Actions

"Interrelated and Interdependent Actions" are actions that would not occur but for the proposed Project, and therefore they are a connected action and effect that must be analyzed together with the proposed Project. The Service's consultation handbook provides a detailed discussion about how to recognize such actions (USDI and USDC 1998; page 4-25).

We do not anticipate any interrelated and interdependent actions with this Project.

7 CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

The Service is not aware of any other future actions that are reasonably certain to occur in the Teanaway watershed that are likely to contribute to cumulative effects on bull trout. For this description of cumulative effects, the Service assumes that future non-Federal activities in the area of the proposed action will continue into the immediate future at present or increased intensities. Accordingly, these actions will contribute to some habitat indicators continuing to "function at risk" or to be "not properly functioning."

Most of the private land in the Teanaway watershed is located in the valley bottom and is used for agriculture or residential development. Continued subdivision of parcels, home building, and well drilling are likely to damage aquatic habitats more rapidly than conservation acquisitions and restoration actions can repair them. As the human population in Washington State continues to grow, demand for rural residential development and dispersed and developed recreation is likely to continue. This trend is likely to result in increasing habitat degradation from housing and road construction, levee building, bank armoring, and campsite development on private lands. These activities tend to remove riparian vegetation (which reduces stream shade, increases stream temperature and reduces the opportunity for large woody debris recruitment), disconnect rivers from their floodplains, interrupt groundwater-surface water interactions, and reduce off-channel rearing habitat. Each subsequent action by itself may have only a small incremental effect, but taken together they may have a substantive effect that will further degrade the watershed's environmental baseline and undermine the improvements in habitat conditions

necessary for listed species to survive and recover. Watershed assessments and education programs may reduce these adverse effects by continuing to raise public awareness about the potentially detrimental effects of residential development and recreation on salmonid habitats and by presenting ways in which a growing human population and healthy fish populations can co-exist.

Easements and land acquisitions for habitat preservation are ongoing throughout the Yakima basin and these efforts are likely to contribute to maintaining or improving habitat quality. These acquisitions not only prevent development and associated habitat degradation, but they also provide opportunities for restoration of fluvial processes that produce and maintain high-quality aquatic habitats.

8 CONCLUSION

After reviewing the current status of the bull trout and its designated critical habitat range-wide, the environmental baseline for the bull trout and its designated critical habitat in the action area, the effects of the proposed action, and cumulative effects, it is the Service's biological opinion that the Project, as proposed, is not likely to jeopardize the continued existence of the coterminous U.S. population of the bull trout, and is not likely to destroy or adversely modify designated critical habitat for the bull trout at the rangewide scale. The following sections describe the key findings of our analyses at each relevant scale.

No Jeopardy Determination

The range-wide status of the bull trout is variable among and within the five interim recovery units that comprise the threatened coterminous U.S. population. Each of these units is necessary to maintain the bull trout's distribution, as well as its genetic and phenotypic diversity, all of which are important to ensure the species' resilience to changing environmental conditions. The Columbia River Interim Recovery Unit (where the action area is located) is especially important to the survival and recovery of the bull trout because it contains nearly 80 percent of all core areas range-wide, and over 80 percent of all local populations within the coterminous U.S. range of the bull trout. The Columbia River Interim Recovery Unit is vast, and contains a mix of core areas with increasing, stable, and declining demographic trends. The Yakima core area is among those with an unstable population trend. Several local populations are currently close to extirpation. Overall abundance levels and migratory connectivity are far below the goal for this unit in the Service's draft recovery plan, and as such is not currently trending toward recovery. The proposed Project would likely maintain this situation. Slight degradation in habitat conditions at the local scale will not be sufficient to change population trends or distribution at the local population, core area, interim recovery unit or range-wide scales.

The Project will have adverse effects on the Teanaway local population in the Yakima Core area. Adverse direct effects and adverse indirect effects to streambanks, riparian areas, and processes that generate off-channel habitat will cause primarily sub-lethal injury of bull trout in all free-swimming life stages. Within the context of all the factors that influence the dynamics of bull

trout populations, we think the scope and severity of these effects will be too limited to result in changes in the reproduction, numbers, or distribution of the core area population affected. We believe the effects of this Project are highly unlikely to shift bull trout population dynamics at the core-area scale, or influence the level of exchange among core areas.

Over the long term, we expect the negative effects of the Project at the local scale to be imperceptible at the larger scales of the core area, interim recovery unit, or coterminous range. Considering the effects of the proposed Project, together with cumulative effects, we believe the status of the bull trout in the Teanaway Watershed and the Yakima Core Area are likely to be maintained with implementation of the Project. Therefore, the proposed action is not likely to jeopardize the continued existence of the bull trout at the range-wide scale.

Incidental take of bull trout is likely to occur as a result of implementation of the proposed action. The Incidental Take Statement accompanying this biological opinion includes mandatory Reasonable and Prudent Measures and Terms and Conditions intended to minimize this incidental take.

No Adverse Modification Determination

The range-wide status of designated critical habitat for the bull trout is variable among and within CHUs. General habitat conditions in the Yakima CHU show a pattern in which lower reaches of drainages are fairly degraded, likely influenced by a high level of development, roads, forestry, agriculture, irrigation diversions, grazing, mining, and other infrastructure and land management. These reaches also have 303(d) listed impairments of water quality, with temperature and instream flow being most common. In contrast, the upper reaches of drainages are generally of higher quality and have less anthropogenic impacts, although there is substantial variation.

The baseline condition of the PCEs of designated critical habitat in the action area is typical of the CHU, with all 9 PCEs "functioning at risk". The degraded baseline condition of PCEs is due to a combination of past and ongoing water withdrawals, logging, grazing, an extensive road network that continues to accelerate sedimentation, and increasing recreation-related degradation of riparian areas.

The proposed Project is likely to adversely affect PCEs 4 and 6 of designated critical habitat for the bull trout by degrading streambank conditions, preventing development of off-channel habitat, altering riparian areas and floodplain connectivity, and changing sediment dynamics. This habitat degradation will be spatially limited to the Project vicinity. While these effects may reduce the capacity of particular sites to support bull trout, these effects are unlikely to change the functional capacity of the entire stream reach where the Project occurs. Conservation measures included in this Project may contribute to improvements in critical habitat function relative to its functional capacity at the time of designation.

We believe these Project effects are consistent with the conservation role of critical habitat range-wide to support viable core area populations. On that basis, implementation of the proposed Project is not likely to destroy or adversely modify bull trout critical habitat at the range-wide scale.

9 REASONABLE AND PRUDENT ALTERNATIVES

Regulations implementing Section 7 of the Act (50 C.F.R. §402.02 *et seq.*) define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that: (1) can be implemented in a manner consistent with the intended purpose of the action; (2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; (3) are economically and technologically feasible; and (4) would, the Service believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

Because the proposed action is not likely to jeopardize the continued existence of the bull trout or destroy or adversely modify proposed critical habitat for the bull trout, no reasonable and prudent alternatives are required.

INCIDENTAL TAKE STATEMENT

1. Introduction

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct. Harm is further defined by Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions or omissions that create the likelihood of injury to listed species by annoying it to such an extent as to significantly disrupt normal behavior patterns which include but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the NRCS so that they become binding conditions of any grant or permit issued to the applicant, as appropriate, for the exemption in section 7(o)(2) to apply. The NRCS has a continuing duty to regulate the activity covered by this incidental take statement. If the NRCS fails to assume and implement the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) will lapse. In order to monitor the impact of incidental take, the NRCS must report the progress of the action and its impact on the species to the Service as specified in this Incidental Take Statement [(50 CFR §402.14(i)(3)].

2. Anticipated Amount or Extent of Take of Bull Trout

In the "Effects of the Action" section of the accompanying biological opinion, the Service estimated the number of bull trout that would be exposed to adverse effects from this Project after making several simplifying assumptions. The rationale for these assumptions is presented in the "Effects of the Action" section. These assumptions necessarily introduce uncertainty into our estimate of incidental take.

The primary mechanisms of incidental take will be (1) harm resulting from direct exposure of juveniles and sub-adults to mechanical injury from substrate compaction, capture and relocation, or stranding, and (2) harm caused by direct exposure to increased suspended sediment during Project construction. The amount of incidental take expected to occur, based on the number of bull trout from different life stages exposed to adverse effects from different project elements, is summarized in the following table:

Table ITS-1: Summary of incidental take of bull trout by severity of effect and life stage.

	Effect Type				
	Direct		Indirect (habitat degradation)		
Life Stage	Lethal	Sub-lethal	Lethal	Sub-lethal	**Total**
Adult	-	-	-		-
Sub-adult/juvenile	-	2	-	Unquantifiable	2
Total	-	2	-		2

All incidental take discussed here will occur to the Teanaway local population in the Yakima Core Area, within the Columbia River Interim Recovery Unit. We expect incidental take to occur during Project construction. We also expect adverse future effects due to Project-related habitat degradation in the form of reduced availability of off-channel habitat. We cannot quantify this effect, but we believe it is likely to be sub-lethal in severity.

The Service acknowledges that the amount of incidental take of bull trout resulting from the Project will be difficult to detect due to: (1) primarily nocturnal activity patterns, tendency to hide in or near the substrate, small body size and cryptic coloration and behavior of juvenile and sub-adult bull trout (2) the low likelihood of finding an injured or dead individual in the relatively complex habitats in the action area, and (3) high rate of removal of injured individuals by predators or scavengers. Given these difficulties, any detection of incidental take can provide valuable information to enable the Service to develop better methods for avoiding and minimizing incidental take, and to refine estimates of incidental take for future projects of a similar nature in similar contexts.

The Service believes that attempts to precisely track the quantity of incidental take occurring during Project implementation would likely result in more harm to bull trout than the Project alone. To comply with the Act, however, the NRCS must ensure that its activities do not result in levels of take exceeding that anticipated in this incidental take statement. We believe that risk of bull trout injury due to substrate compaction and handling is proportional to the size of the wetted area that is dewatered, the length of the coffer dam installed, and the number of times dewatering and fish rescue occurs. If the length of cofferdam installed is greater than 350 feet, or if flooding or other circumstances require fish removal from the work area to occur more than once, then incidental take of bull trout may be exceeded and consultation with the Service should be reinitiated. Regarding incidental take due to exposure to suspended sediment, we believe that monitoring turbidity as proposed in the Project description will provide an index of direct adverse effects. If more than two sediment plumes are produced during construction, or plumes extend more than 600 feet downstream from the work site, or if measured turbidity is elevated by more than1,000 micrograms per liter (mg/L) of suspended solids above background levels for a period of 3 hours, expected levels of incidental take due to increased sedimentation may be exceeded and consultation with the Service should be reinitiated.

3. Effect of the Take

In the accompanying Biological Opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species.

4. Reasonable and Prudent Measures
No reasonable and prudent measures are necessary and appropriate to minimize take of bull trout for the proposed Project.

5. Terms and Conditions
Because the Service did not develop any Reasonable and Prudent Measures, we do not specify any terms and conditions.

6. Reporting Requirements
In order to monitor the impacts of implementation of the reasonable and prudent measures, the NRCS shall prepare a report describing the progress of the proposed Project, and impacts to the bull trout (50 CFR § 402.14(I)(3)). The report, which shall be submitted to the Central Washington Field Office on or before March 1 of the year following monitoring, shall list and describe:

1. Adverse effects to bull trout resulting from Project activities including number and life stages of affected individuals detected, if any.
2. Dates when Project implementation began and ended for the reporting year.
3. Deviations from proposed Project description.
4. Results of all monitoring activities.
5. Implementation of any conservation recommendations.

Upon locating a dead, injured, or sick specimen of an endangered or threatened species, initial notification must be made to the nearest Service Law Enforcement Office (Richland, Washington; Special Agent Corky Roberts, telephone 509-546-8344). Care should be taken in handling sick or injured specimens to ensure effective treatment and care or the handling of dead specimens to preserve biological material in the best possible state for later analysis of cause of death. In conjunction with the care of sick or injured endangered species or preservation of biological materials from a dead animal, the finder has the responsibility to carry out instructions provided by Law Enforcement to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed.

The Service believes that no more than 2 bull trout will be incidentally taken as a result of the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiating of consultation. The NRCS must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures. Because incidental take for this Project is difficult to estimate and detect, the Service must be contacted if implementation plans change substantially from those described and the project effects no longer fall within the effects analyzed in the accompanying biological opinion.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service provides the following recommendations:

CR 1. Require applicants seeking assistance with bank protection projects to evaluate and consider alternatives that do not interrupt fluvial processes.

CR 2. Coordinate regularly with entities conducting river restoration to identify opportunities to promote restoration of natural fluvial processes in future projects.

In order to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action outlined in the request. As provided in 50 CFR §402.16, reinitiating of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

LITERATURE CITED

Alabyan, A.M., and R.S. Chalov. 1998. Types of river channel patterns and their natural controls. Earth Surface Processes and Landforms **23**: 467-474.

Allendorf, F.W., and R.F. Leary. 1986. Heterozygosity and fitness in natural populations of animals. Pages 57-76 in M.E. Soule' editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates.

Ardren, W.R., P.W. DeHaan, T.S. Christian, E.B. Taylor, R. Leary, C. Kozfkay, L. Godfrey, M. Diggs, W. Fredenberg, J. Chan, C.W. Kilpatrick, M.P. Small, D.K. Hawkins, 2010. Genetic structure, evolutionary history, and conservation units of bull trout in the coterminous United States. U.S. Fish and Wildlife Service. Longview, WA.

Bash. J., C. Berman and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Technical Report WA-RD 526.1 prepared by the U. of Wash. Transportation Center for the Washington State Transportation Commission in cooperation with the US Dept. Of Transportation, Federal Highways Administration. Seattle, WA, USA. 92 pp.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceeding of the National Acadmey of Sciences of the Unites States of America. *PNAS* published online April 5, 2007. www.pnas.org.

Berg, L., and T. G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Can. J. Fish. Aquat. Sci. **42**: 1410-1417.

BioAnalysts, Inc., 2004. Movement of Bull Trout in the Mid-Columbia River and Tributaries, 2001-2004. Report prepared for Chelan, Douglas, and Grant PUDs.

Bisson, P.A., B.E. Rieman, C. Luce, P.F. Hessburg, D.C. Lee, J.L. Kershner, G.H. Reeves, and R.E. Gresswell. 2003. Fire and aquatic ecosystems of the western USA: Current knowledge and key questions. Forest Ecology and Management 178:213-220.

Bolton, S. and J. Shellberg. 2001. Ecological issues in floodplains and riparian corridors. White Paper: Washington Department of Fish and wildlife, Washington Department of Ecology, and Washington Department of Transportation. University of Washington, Center for Stream Studies. Seattle, WA.

Bond, C.E. 1992. Notes on the nomenclature and distribution of the bull trout and the effects of human activity on the species. Pages 1-4 *In*: Howell, P.J. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.

Braatne, J.H. and B. Jamieson. 2001. The impacts of flow regulation on riparian cottonwood forests of the Yakima River. Prepared for the Bonneville Power Administration, Contract No. 00000005, Project No. 200006800,(BPA Report DOE/BP-00000005-3). Report to Bonneville Power Administration, Portland, OR. 69 pp.

Brewin P.A. and M. K. Brewin. 1997. Distribution Maps for Bull Trout in Alberta. Pages 206-216 *in:* Mackay, W.C., M.K. Brewin and M. Monita, editors. Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Calgary, Alberta, Canada.

Casola, J.H.; Kay, J.E.; Snover, A.K.; Norheim, R.A.; Whitely Binder, L.C.; the Climate Impacts Group. 2005. Climate impacts on Washington's hydropower, water supply, forests, fish, and agriculture. A report prepared for King County (Washington) by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle). 43 p.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout *Salvelinus confluentus* (Suckley), from the American northwest. Calif. Fish and Game 64:139-174.

Center for Disease Control, Agency for Toxic Substances and Disease Registry. 2002. ToxFaqs for DDT, DDE, and DDD. Atlanta, GA.

Craig, S.D. 1997. Habitat conditions affecting bull trout (*Salvelinus confluentus*) spawning areas within the Yakima River Basin, Washington. Master of Science thesis, Central Washington University, Ellensburg, WA. 74 pp.

Creech, J and J. Joy. 2002. Upper Yakima River Basin Suspended Sediment, Turbidity and Organochlorine Pesticide Total Maximum Daily Load -- Submittal Report. Publication number 02-10-047, Washington Department of Ecology, Olympia, WA.

Cuffney, T. F., M. R. Meador, S. D. Porter and M. E. Gurtz. 1997. Distribution of fish, benthic invertebrate, and algal communities in relation to physical and chemical conditions, Yakima River Basin, Washington, 1990. Water Resources-Investigations Report 96-4280. U.S. Geological Survey, Raleigh, NC. 94 pp.

Dawson, P. 1999. Biological assessment for steelhead, bull trout and cutthroat trout for the proposed actions in the Little Naches watershed. USDA Forest Service, Wenatchee National Forest, Naches Ranger District. Wenatchee, WA; January 29, 1999.

Downs, C.C., D. Horan, E. Morgan-Harris and R. Jakubowski. 2006. Spawning demographics and juvenile dispersal of an adfluvial bull trout population in Trestle Creek, Idaho. North American Journal of Fisheries Management 26:190-200.

Dunham, J.B. and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of habitat size, isolation, and human disturbance. Ecological Applications 9(2): 642-655.

Dunham, J., B. Rieman, and K. Davis. 2001. Sources and magnitude of sampling error in redd counts for Bull Trout. North American Journal of Fisheries Management 21:343–352.

Dunne, T., and Leopold, L.B. 1978. Water in Environmental Planning: Freeman, San Francisco, CA; 818 p.

Ebbert, J.C., and S.S. Embrey. 2001. Pesticides in surface water of the Yakima River Basin, Washington, 1999-2000: Their occurrence and an assessment of factors affecting concentrations and loads. U.S. Geological Survey. Water Resources Investigations Report 01-4211. 49 pp.

Eitemiller, D.J., M.L. Uebelacker, D.A. Plume, E.P. Arango and K.L. Clark. 2000. Anthropogenic alteration to an alluvial flood plain within the Yakima Basin, Washington. *In*: P.J. Wigington, Jr. and R.L. Beschta (eds.). Proceedings of the AWRA 2000 Summer International Specialty Conference on Riparian ecology and Management in Multi-Land Use Watersheds. pp.239-244.

Extoxnet. 1996. Pesticide information profiles (PIP). Cooperative Extension Offices, University of Idaho, Oregon State University, Cornell University, University of California at Davis, and Michigan State University. Corvallis, OR. 4 p.

Foltz, R. B. , Yanosek, K.A. and T. M. Brown. 2008. Sediment concentration and turbidity changes during culvert removals. Journal of Environmental Management 87:329-340.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, MT. Northwest Science 63 (4): 133-143

Frissell, C.A. 1993. Topology of extinction and endangerment of native fishes in the Pacific Northwest and California. Conservation Biology 7:342-354.

Fuhrer, G., D. Cain, S. MacKenzie, J. Rinela, J. Crawford, K. Skach, and M. Hornberger. 1987. Surface-Water-Quality Assessment of the Yakima River Basin in Washington: Spatial and temporal distribution in water, sediment, and aquatic biota, 1987. U.S. Geological Survey, Portland, OR.

Hamilton, S. and R. Wiedmeyer. 1990. Concentrations of boron, molybdenum, and selenium in chinook salmon. Transact. Of the Amer, Fish. Soc. 119:500-510.

Hard, J. 1995. A quantitative genetic perspective on the conservation of intraspecific diversity. American fisheries Society Symposium 17:304-326.

Hari, R. E., D. M. Livingstone, R. Siber, P. Burkhardt-Holm, and H. Guttinger. 2006. Consequences of climatic change for water temperature and brown trout populations in alpine rivers and streams. Global Change Biology 12:10-26.

Harvey, B. C. and T. E. Lisle. 1998. Effects of suction dredging on streams: A review and an evaluation strategy. Fisheries 23(8):8-17.

Hawkins, D.K. and J. Von Bargen. 2006. Microsatellite analysis of Yakima basin bull trout. Unpublished WDFW Molecular Genetics Laboratory Report submitted to Eric Anderson, WDFW.

Healy, M.C. and A. Prince. 1995. Scales of variation in life history tactics of Pacific salmon and the conservation of phenotype and genotype. American Fisheries Society Symposium 17:176-184.

Hicks, B. J., J. D. Hall, P. A. Bisson and J. R. Sedell. 1991. Response of salmonid populations to habitat changes caused by timber harvest. pp. 438-518, In: W. R. Meehan (ed.). Influence of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, MD.

Hoelscher, B. and T.C. Bjorn. 1989. Habitat, density and potential production of trout and char in Pend Oreille Lake tributaries. Project F-71-R-10, Subproject III, Job No. 8.Idaho Department of Fish and Game, Boise, ID.

Howell, P.J., and D.V. Buchanan. 1992. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. ISAB 2007-2. Portland, Oregon.

James, P.W. 2002. Population status and life history characteristics of bull trout in the Yakima River Basin. Central Washington University, Department of Biological Sciences, Ellensburg, WA. Final report. 78 pp.

Johnson, A., D. Norton, and B. Yake. 1986. Occurrence and significance of DDT compounds and other contaminants in fish, water and sediment from the Yakima River Basin, Washington Dept. of Ecology, Water Quality Investigations Section. 89 pp.

Joy, J. 2002. The Upper Yakima Basin Suspended Sediment and Organochlorine Pesticide TMDL Study. Washington Department of Ecology. Olympia, WA.

Joy, J., and B. Patterson. 1997. A suspended sediment and DDT total maximum daily load evaluation report for the Yakima River. Washington Department of Ecology, Publication No. 97-321, Olympia, WA.

Kentucky Water Watch (State of Kentucky). 2004. pH. State of Kentucky (www.state.ky.us/nrepc/water).

Kinnison, H. B. and J. E. Sceva. 1963. Effects of Hydraulic and Geologic Factors on Streamflow of the Yakima River Basin Washington. U.S. Geological Survey Water Supply Paper 1595. U.S. Government Printing Office, Washington, D.C. 135 pp.

Leary, R.F. and F.W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Transactions of the American Fisheries Society 126:715-720.

Leary, R.F., F. W. Allendorf, and S. H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology, Volume **7**, No. 4, December 1993.

Leopold, L.B., M.G. Wolman and J.P. Miller. 1964. Fluvial processes in geomorphology. W.H. Freeman and Company, San Francisco, CA.

MBTSG (Montana Bull Trout Scientific Group). 1998. The relationship between land management activities and habitat requirements of bull trout. Montana Bull Trout Restoration Team. Helena, Montana.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown. 1994. Historical changes in fish habitat for selected river basins of eastern Oregon and Washington. Northwest Science **68**:36-53.

McKie, P., and W. Johnson. 2004. Water pH and effect on pesticide stability. Cooperative Extension, University of Nevada, Reno, Reno, NV.

Meyer, W.R. 2002. The effects of seasonal stream de-watering on three age classes of bull trout (*Salvelinus confluentus*). Master of Science thesis, Central Washington University, Ellensburg, WA. 84 pp.

Mizell, M. and Anderson, E. 2006. An investigation into the migratory behavior, habitat use and genetic composition of bull trout (*Salvelinus confluentus*) in the Yakima River Basin. Draft Report. Washington Department of Fish and Wildlife. 243 pp.

Morace, J.L., G.J. Fuhrer, J.F. Rinella, S.W. McKenzie, and others. 1999. Surface-water-quality assessment of the Yakima River Basin, Washington-Overview of significant findings: U.S. Geological Survey Water-Resources Investigations Report 98-4113, 119 pp.

Muhfeld, C. C. and B. Marotz. 2005. Seasonal movement and habitat use by subadult bull trout in the upper Flathead River system, Montana. North American Journal of Fisheries Management. 25(3):797-810.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, and J.D. McIntire. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. U.S. Fish and Wildlife Service. Monograph I.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. N. Am. J. Fish. Manag. 11: 72-82.

Newcombe, C. P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. N. Am. J. Fish. Manag. 16: 693–727.

National Marine Fisheries Service (NMFS). 2000. Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act. National Marine Fisheries Service. June.

NPPC (Northwest Power Planning Council). 2001. Yakima subbasin summary. Prepared by L. Berg and D. Fast.

Overton, C.K., M.A. Radko, and R.L. Nelson. 1993. Fish habitat conditions; using the Northern/intermountain region's inventory procedures for detecting differences on two differently managed watersheds. U.S. Forest Service Intermountain Research Station, Boise, ID.

Pratt, K.L. 1992. A review of bull trout life history. Pages 5 - 9 *in:* Howell, P.J. and D.V. Buchanan, eds., Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.

Quigley, T.M., and S.J. Arbelbide, tech. eds. 1997. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: volume III. Gen. Tech. Rep. PNW-GTR-405.: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 4 vol.

Reiss, Y. 2003. Genetic Variability within Bull Trout (*Salvelinus confluentus*) populations in the Yakima River Basin. M.S.Thesis, Central Washington University, Ellensburg, WA.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. United States Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT_302, Ogden, UT. 38 pp.

Rieman, B.E., and F.W. Allendorf.. 2001. Effective population size and genetic conservation criteria for bull trout. North Am. J. Fisheries Management 21: 756-764.

Rieman, B. E., J. T. Peterson, and D. L.Myers. 2006. Have brook trout (*Salvelinus fontinalis*) displaced bull trout (*Salvelinus confluentus*) along longitudinal gradients in central Idaho streams? Canadian Journal of Fisheries and Aquatic Sciences 63:63–78.

Rieman, B. E., D. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Meyers. 2007. Anticipated Climate Warming Effects on Bull Trout Habitats and Populations Across the Interior Columbia River Basin. Transactions of the American Fisheries Society 136:1552-1565.

Rinella, J.F., S. W. McKenzie, and G. J. Fuhrer. 1992. Surface-Water-Quality Assessment of the Yakima River Basin, Washington: Analysis of Available Water-Quality Data Through 1985 Water Year. US Geological Survey Open-File Report 91-453, Portland, OR.

Rinella, J. F., P. A. Hamilton and S. W. McKenzie. 1993. Persistence of the DDT pesticide in the Yakima River Basin, Washington. U. S. Government Printing Office, US Geological Survey Circular 1090. 24 pp.

Sigler, J. W., T.C. Bjornn, and F. H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American. Fisheries Society 113: 142-150.

Snyder, E. and J. Stanford. 2001. Review and Synthesis of River Ecological Studies in the Yakima River, Washington, With Emphasis on Flow and Salmon Habitat Interactions. Flathead Lake Biological Station, University of Montana, Polson, MT. 118 pp.

Spruell, P., A.R. Hemmingsen, P.J. Howell, N. Kanda, and F.W. Allendorf. 2003. Conservation genetics of bull trout: geographic distribution of variation at microsatellite loci. Conservation Genetics 4:17-19.

Stanford, J., E. Snyder, M. Lorang, D. Whited, P. Matson, and J. Chaffin. 2002. The Reaches Project: ecological and geomorphic studies supporting normative flows in the Yakima River Basin, Washington. Open Report 170-02. Report prepared for the Yakima Office, Bureau of Reclamation, U.S. Department of the Interior, Yakima, Washington by Flathead Lake Biological Station, University of Montana, Polson, MT. 152 pp.

Suttle, K.B., M.E. Power, J.M. Levin, and C. McNeely, 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. *Ecological Applications* 14: 969-974.

Thurow, R. F., J. T. Peterson, C. A. Larsen, and J. W. Guzevich. 2004. Development of bull trout sampling efficiency models final report. U.S. Forest Service, Rocky Mountain Research Station, and U. S. Geological Survey, Boise, Idaho, and Georgia Cooperative Fish and Wildlife Research Unit, Athens, Georgia. 69 pp.

Tri-County Water Resources Agency. 2001. *Watershed Assessment, Yakima River Basin, Final Document, performed by Yakima River Basin Watershed Planning Unit and Tri-County WaterResources Agency.* January 2001. Prepared by Economic and Engineering Services, Inc., in association with Montgomery Water Group, Inc.; R.C. Bain & Associates; Dames & Moore; Tim Reierson; Marshall & Associates; Stuart McKenzie; Parametrix, Inc.; Larry Vinsonhaler; EnviroIssues; and Newell Campbell.

U.S. Bureau of Reclamation (USBR). 1999. Programmatic Environmental Impact Statement. Yakima River Basin Water Enhancement Project, Washington. Pacific Northwest Region, Upper Columbia Area Office, Yakima, WA.

USDA (U.S. Department of Agriculture), USDI (U.S. Department of Interior), and USDC (United States Department of Commerce), 2004. Interagency Training: Analytical Process for Developing Biological Assessments for Federal Actions Affecting Fish Within the Northwest Forest Plan Area. Bureau of Land Management, Fish and Wildlife Service, Forest Service, NOAA Fisheries – National Marine Fisheries Service.

USDI and USDC (United States Department of Interior and United States Department of Commerce). 1998. Endangered species consultation handbook.

USEPA (United States Environmental Protection Agency). 2003. EPA Region 10 guidance for Pacific Northwest state and tribal temperature Water Quality Standards. U.S. Environmental Protection Agency, Region 10, Office of Water, Seattle, Washington. 49 pp.

USFS (United States Forest Service). 1996. Cle Elum watershed analysis. U.S. Department of Agriculture, Forest Service, Cle Elum Ranger District, Wenatchee National Forest, Wenatchee, WA.

USFS (United States Forest Service). 1998. Teanaway Watershed Analysis. U.S. Department of Agriculture, Forest Service, Cle Elum Ranger District, Wenatchee National Forest, Wenatchee, WA.

USFS (U.S. Forest Service). 2004. Comparison of Yakima Basin allele frequencies to Spruell (2003) samples in the northwest: e-mail and file from Yuki Reiss, Wenatchee National Forest, Wenatchee, WA.

USFWS (U.S. Fish and Wildlife Service). 2010. Bull Trout Final Critical Habitat Justification: Rationale for Why Habitat is Essential, and Documentation of Occupancy. U.S. Fish and Wildlife Service, Pacific Region. Portland, OR.

USFWS (U.S. Fish and Wildlife Service). 2008. Bull trout 5-year review. U.S. Fish and Wildlife Service, Regions 1, 6, and 8. Portland, OR.

USFWS (U.S. Fish and Wildlife Service). 2007. Biological Opinion for the Priest Rapids Hydroelectric License Renewal. U.S. Fish and Wildlife Service, Region 1, Wenatchee, WA.

USFWS (U.S. Fish and Wildlife Service). 2006. Biological Opinion for the Rock Creek Mine. U.S. Fish and Wildlife Service, Region 6, Helena, MT.

USFWS (U.S. Fish and Wildlife Service). 2006b. Biological Opinion for the Rocky Reach Hydroelectric License Renewal. U.S. Fish and Wildlife Service, Region 1, Wenatchee, WA.

USFWS (U.S. Fish and Wildlife Service). 2005. Designation of critical habitat for the bull trout. Federal Register: 70 (185) 56212-56311.

USFWS (United States Fish and Wildlife Service). 2004a. Draft Recovery Plan for the Jarbidge River Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). U. S. Fish and Wildlife Service, Portland, Oregon. 132 + xiii pp.

USFWS (United States Fish and Wildlife Service). 2004b. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). Volume I (of II): Puget Sound Management Unit, Portland, Oregon. 389 + xvii pp.

USFWS (United States Fish and Wildlife Service). 2002a. Bull trout (*Salvelinus confluentus*) draft recovery plan. U. S. Fish and Wildlife Service, Portland, Oregon.

USFWS (United States Fish and Wildlife Service). 2002b. Chapter 22, Upper Columbia Recovery Unit, Washington. *In*: Bull trout (*Salvelinus confluentus*) draft recovery plan. U. S. Fish and Wildlife Service, Portland, Oregon. 113 pp.

USFWS (United States Fish and Wildlife Service). 1999. Draft. A Framework to Assist in Making Endangered Species Act Determinations of Effect for individual of Grouped Actions at the Bull Trout Subpopulation Watershed Scale. June 1999. 46 pp.

USGS (U.S. Geological Survey). 2002. USGS Pesticide National Synthesis Report. Washington, D.C. (www. water.wr.usgs/pnsp).

Waters, T.F. 1995. Sediment in streams: Sources, biological effects and controls. American Fisheries Society Monograph 7, Bethesda, MD.

WDOE. (Washington Department of Ecology). 2007. Summary of stream gauge temperature data from long term monitoring stations. Taken from WDOE website. Graphs and spreadsheets are on file at Western Washington Office.

WDFW (Washington Department of Fish and Wildlife). 1998. Washington State salmonid stock draft inventory: bull trout/Dolly Varden. Washington Department of Fish and Wildlife, Olympia, WA.

WDFW (Washington Department of Fish and Wildlife). 2010. An Investigation into the Migratory Behavior, Habitat Use and Genetic Composition of Fluvial and Resident Bull Trout (*Salvelinus confluentus*) in the Yakima River Basin. Draft Report. Mike Mizell and Eric Anderson.

WDOE (Washington Department of Ecology). 1998. 1995 Fish tissue sampling report. Olympia WA.

WDOE (Washington Department of Ecology). 2002. Upper Yakima River Basin suspended sediment, turbidity, and organochlorine pesticide total maximum daily load. Pub. No. 02-10-047-W Q. Olympia WA.

Whitesel, T.A. et.al. 2004. Bull trout recovery planning: A review of the science associated with population structure and size. Science Team Report #2004-01, U.S. Fish and Wildlife Service, Portland, Oregon. 41 pp plus lit cited and appendices.

WSCC (Washington State Conservation Commission). 2001. Salmon and steelhead habitat limiting factors, Yakima River Waterhed. Water Resource Inventory Areas 37 – 39, Final Report. Washington State Conservation Commission, Olympia, Washington.

WWF (World Wildlife Fund). 2003. Buying time: a user's manual for building resistance and resilience to climate change in natural systems. Editors: L.J. Hansen, J.L Biringer, and J.R.Hoffman.

YBFWPB (Yakima Basin Fish and Wildlife Planning Board). 2004. Yakima Subbasin Plan. Yakima, Washington.

YBFWRB (Yakima Basin Fish and Wildlife Recovery Board). 2005. Yakima Salmon and Bull Trout Recovery Plan. Yakima, Washington.

YSF&WPB (Yakima Subbasin Fish and Wildlife Planning Board). 2004. Yakima Subbasin Plan. Prepared for the Northwest Power and Conservation Council, May 28, 2004. Yakima,WA.

Personal Communications

Anderson, E., 2002. Washington Department of Fish and Wildlife, Yakima, WA.
Subject: Stranding of bull trout and flow fluctuations in the Yakima River.

De La Vergne, J., 2003. USFWS, Fish and Wildlife Biologist, Central Washington Field Office, 215 Melody Lane, Suite 119, Wenatchee, Washington, 98801
Subject: Bull trout biology

Krupka, J., 2003. Fish and Wildlife Biologist, Central Washington Field Office, 215 Melody Lane, Suite 119, Wenatchee, Washington, 98801
Subject: Section 9 violations in Ahtanum watershed.

Spruell, P., 2004. University of Montana. Missoula, MT.
Subject: Bull trout genetics.

APPENDIX A: Bull Trout Life History and Population Dynamics

1. Historic and Current Range

Bull trout are native to northwestern North America, historically occupying a large geographic range extending from California north into the Yukon and Northwest Territories of Canada and east into western Montana and Alberta (Cavender 1978). They are generally found in interior drainages, but also occur on the Pacific Coast in Puget Sound and in the large drainages of British Columbia.

The historic range of the bull trout is likely to have contracted and expanded over time in relation to natural environmental and climate changes; the distribution of the species was likely patchy even in pristine environments. Despite uncertainty about the exact historical range, the number and size of historical populations, and the role of natural factors in the status of the species, there is widespread agreement in the scientific literature that many factors related to human activities have impacted bull trout and continue to pose significant risks of further extirpations of local populations.

Bull trout currently occur in rivers and tributaries in Montana, Idaho, Washington, Oregon (including the Klamath River basin), Nevada, two Canadian Provinces (British Columbia and Alberta), and several cross-boundary drainages in southeast Alaska. East of the Continental Divide, bull trout are found in the headwaters of the Saskatchewan River in Alberta, and the MacKenzie River system in Alberta and British Columbia (Cavender 1978; McPhail and Baxter 1996; Brewin and Brewin 1997). The current distribution of bull trout is highly fragmented.

The distribution of bull trout has shrunk in the Pacific Northwest and northern California. The distribution of bull trout has been reduced by an estimated 55 percent in the Klamath River DPS and 79 percent in the Columbia River DPS since pre-settlement times, due primarily to local extirpations, habitat degradation, and isolating factors (Quigley and Arbelbide 1997). Within the Puget Sound basin, bull trout distribution is similar to historic conditions, but population abundance has significantly decreased. In California, bull trout were historically found only in the McCloud River, which represented the southernmost extension of the species' range. The last confirmed report of bull trout in the McCloud River was in 1975, and this population is now considered to be extirpated (Rode 1990).

2. Life History

Bull trout populations exhibit three different life-history types: resident, migratory, and anadromous. Resident and migratory forms exist throughout the range of the bull trout (Rieman and McIntyre 1993) and spend their entire lives in freshwater. The anadromous life- history form is currently only known to occur in the Coastal-Puget Sound region within the coterminous United States (Volk 2000; Kraemer 1994; Mongillo 1993). Multiple life-history types may be expressed in the same population, and diversity of life-history types is considered important to the stability and viability of bull trout populations (Rieman and McIntyre 1993).

Life history type determines where the majority of the growth and maturation occurs. Anadromous bull trout growth and maturation mostly occurs in estuarine and marine waters. Juvenile bull trout displaying the anadromous life history spend 1 to 3 years near freshwater natal areas before moving to estuary and/or nearshore marine areas to mature (Rieman and McIntyre 1993). Migratory bull trout mostly grow and mature in lakes, reservoirs, and large river systems. Like anadromous bull trout, juvenile migratory bull trout typically rear in or near natal streams for 1 to 3 years before migrating downstream into larger rivers or lakes. In some systems, age 0+ fish may migrate directly to lakes (Riehle et al. 1997). Resident bull trout populations are generally found in small headwater streams where the fish remain for their entire lives.

2.1 Freshwater Habitat

Bull trout have more specific habitat requirements than other salmonids (Rieman and McIntyre 1993). Growth, survival, and long-term persistence are dependent upon several habitat characteristics, including: cold water, complex instream habitat, a stable substrate with a low percentage of fine sediments, high channel stability, and connectivity among streams supporting bull trout populations. Stream temperature and substrate type, in particular, are critical factors for the long-term persistence of bull trout. Spawning is often associated with the coldest, cleanest, and most complex stream reaches within basins. Consequently, bull trout exhibit a patchy distribution, even in pristine habitats (Rieman and McIntyre 1995), and should not be expected to occupy all available habitats at the same time (Rieman et al. 1997a).

Although bull trout clearly prefer cold waters and nearly pristine habitat, they can occur in degraded habitats. It is likely that small remnant populations of bull trout persisting in degraded rivers are using less than optimal habitat because that may be all that is available. In basins with high productivity, such as the Skagit River basin, bull trout may be using marginal areas when optimal habitat becomes fully occupied (C. Kraemer, WDFW, pers. comm. 2002). Bull trout have been documented using habitats that may be atypical or characterized as likely to be unsuitable (USFWS 2000).

2.1.1 Temperature. Bull trout are typically associated with the coldest stream reaches within basins. For long-term persistence, bull trout populations need a stream temperature regime that ensures sufficient amounts of cold water are present at the locations and during the times needed to complete their life cycle. Temperature is most frequently recognized as the factor limiting bull trout distribution (Dunham et al. 2003a; Dunham and Chandler 2001; Rieman and McIntyre 1993), which partially explains their generally patchy distribution within watersheds (Fraley and Shepard 1989; Rieman and McIntyre 1995). When maximum daily temperatures did not exceed approximately 11 to 12° C, the probability of occurrence for juvenile bull trout in Washington was high (75 percent) (Dunham et al. 2001). The most productive bull trout habitat in several Oregon streams had temperatures which seldom exceeded 15 °C (Buckman et al. 1992; Ratcliff 1992; Ziller 1992).

Stream temperatures must drop below 9 or 10 °C before spawning occurs (McPhail and Murray 1979; Riehle 1993). Water temperature also seems to be an important factor in determining early survival, with cold water temperatures resulting in higher egg survival and faster growth rates for fry and juveniles (Pratt 1992). Optimum incubation temperatures range from 2 to 6 °C, while at

8 to 10 °C, survival ranged from 0 to 20 percent (McPhail and Murray 1979). Stream temperatures for tributary rearing juvenile bull trout are also quite low, ranging from 6 to 10 °C (Buchanan and Gregory 1997; Goetz 1989; Pratt 1992; McPhail and Murray 1979).

Although bull trout require a narrow range of cold water temperatures to rear, migrate, and reproduce, they are known to occur in larger, warmer river systems that may cool seasonally, and which provide important migratory corridors and forage bases. For migratory corridors, bull trout typically prefer water temperatures ranging between 10 to 12 °C (McPhail and Murray 1979; Buchanan and Gregory 1997). When bull trout migrate through stream segments with higher water temperatures they tend to seek areas offering thermal refuge such as confluences with cold tributaries (Swanberg 1997), deep pools, or locations with surface and groundwater exchanges in alluvial hyporheic zones (Frissell 1999).

Increases in stream temperatures can cause direct mortality, increased susceptibility to disease or other sublethal effects, displacement by avoidance (McCullough et al. 2001, Bonneau and Scarnechia 1996), or increased competition with species more tolerant of warm stream temperatures (Rieman and McIntyre 1993; Craig and Wissmar 1993 cited in USDI 1997; MBTSG 1998). Brook trout, which can hybridize with bull trout, may be more competitive than bull trout and displace them, especially in degraded drainages containing fine sediment and higher water temperatures (Selong et al. 2001; Leary et al. 1993). Recent laboratory studies suggest bull trout are at a particular disadvantage in competition with brook trout at temperatures >12 °C (McMahon et al. 2001; Selong et al. 2001).

2.1.2 Substrate. Bull trout show a strong affinity for stream bottoms and a preference for deep pools in cold water streams (Goetz 1989; Pratt 1992). Stream bottom and substrate composition are highly important for spawning site selection and juvenile rearing (Rieman and McIntyre 1993; Graham et al 1981; McPhail and Murray 1979). Fine sediments can influence incubation survival and emergence success (Weaver and White 1985; Pratt 1992; Suttle et al. 2004) but may also limit access to substrate interstices that are important cover during rearing and over-wintering (Goetz 1994; Jakober 1995). Rearing densities of juvenile bull trout have been shown to be lower when there are higher percentages of fine sediment in the substrate (Shepard et al. 1984). Due to this close connection to substrate, bed load movements and channel instability can negatively influence the survival of young bull trout.

2.1.3 Cover and Stream Complexity. Bull trout of all age classes are closely associated with cover, especially during the day (Baxter and McPhail1997; Fraley and Shepard 1989). This association appears to be more important for bull trout than for other salmonids (Pratt 1992; Rieman and McIntyre 1993). Cover may be in the form of overhanging banks, deep pools, turbulence, large wood, or debris jams. Young bull trout also use interstitial spaces in the substrate for cover. Bull trout distribution and abundance are positively correlated with pools and complex forms of cover, such as large or complex woody debris and undercut banks, but may also include coarse substrates (cobble and boulder) (Rieman and McIntyre 1993; Jakober 1995; MBTSG 1998). Juvenile and adult bull trout frequently inhabit side channels, stream margins and pools with suitable cover (Sexauer and James 1993) and areas with cold hyporheic zones or groundwater upwellings (Baxter and Hauer 2000).

Large pools offeringa wide range of water depths, velocities, substrates, and cover, are characteristic of high quality aquatic habitat and are an important component of channel complexity. Large wood in streams creates pools and undercut banks, deflects streamflow, retains sediment, stabilizes the stream channel, increases hydraulic complexity, and improves feeding opportunities (Murphy 1995). All these functions of large wood enhance the quality of habitat for salmonids and contribute to channel stability (Bisson et al. 1987). By forming pools and retaining sediment, large wood also helps maintain water levels in small streams during periods of low stream flow (Lisle 1986).

Reduction of wood in stream channels, either from present or past activities, generally reduces pool frequency, quality, and channel complexity (Bisson et al. 1987; House and Boehne 1987; Spence et al. 1996). Studies conducted with Dolly Varden, a species similar to bull trout, showed that population density declined with the loss of woody debris after clearcutting or the removal of logging debris from streams (Bryant 1983; Dolloff 1986; Elliott 1986; Murphy et al. 1986).

2.1.4 Channel and Hydrologic Stability. Maintaining bull trout habitat requires stream channel and flow stability (Rieman and McIntyre 1993). Bull trout are exceptionally sensitive to activities that directly or indirectly affect stream channel integrity. Juvenile and adult bull trout frequently inhabit areas of reduced water velocity, such as side channels, stream margins, and pools that are easily eliminated or degraded by management activities (Rieman and McIntyre 1993).

Channel dewatering caused by low flows and bed aggradation (accumulation of rock and sediment) can block access for spawning fish, resulting in year class failures (Weaver 1992). Aggradation of the streambed can be accelerated by management activities that increase the frequency of landslides (e.g., road building and timber harvest) or that constrict stream channels (e.g., undersized culverts at stream crossings).

Patterns of stream flow and the frequency of extreme flow events that influence substrates may be important factors in population dynamics (Rieman and McIntyre 1993). With lengthy overwinter incubation and a close tie to the substrate, embryos and juveniles may be particularly vulnerable to flooding and channel scour associated with the rain-on-snow events that are common in some parts of the range (Rieman and McIntyre 1993).

2.1.5 Migration and Habitat Connectivity. Bull trout are highly migratory. The persistence of migratory bull trout populations requires intact migration corridors. Migration corridors link wintering areas with foraging, spawning, and rearing areas used at different times of the year, and by different life-history stages (MBTSG 1998, Rieman and McIntyre 1993). In the Coastal-Puget Sound DPS, migratory corridors may link marine and freshwater habitats as well as linking lake, river, and tributary complexes that are necessary for bull trout to complete their life cycle. Migratory corridors also link local populations, providing opportunities for gene flow and demographic exchange.

Bull trout migratory movements include both spawning migrations and downstream emigration of juveniles from headwater rearing areas to feeding and maturation areas. Migratory bull trout may begin their spawning migrations as early as April and have been known to migrate upstream as far as 250 kilometers (155 miles) to spawning grounds (Fraley and Shepard 1989). Current radio-telemetry work being done in the upper Columbia River basin is revealing movement patterns of migratory bull trout that extend over 160 kilometers (100 miles), from the headwaters of the Wenatchee and Methow basins to the Columbia River and the pools formed by Rocky Reach, Rock Island, and Wells Dams (J. De La Vergne, pers. comm. 2001; BioAnalysts 2004). During these long migrations, bull trout use a wide variety of habitats. Compared to spawning migration, relatively little published information is available about juvenile emigration. Age of emigration varies from one to three years old (Rieman and McIntyre 1993), and annual timing of emigration is highly variable and can extend from spring until winter.

Stream habitat alterations that restrict or eliminate bull trout migration corridors include degradation of water quality (especially increasing temperatures and increased amounts of fine sediments), alteration of natural stream flow patterns, impassable barriers (such as dams and culverts), and structural modification of stream habitat (such as channelization or removal of cover). Dam and reservoir construction and operations have altered major portions of bull trout habitat throughout the Columbia River basin. Dams without fish passage create barriers to fluvial and adfluvial bull trout which isolates populations. The operations of dams and reservoirs alter the natural hydrograph, thereby affecting forage, water temperature, and water quality (USDI 1997). Many populations of "resident" bull trout that are isolated above artificial barriers to migration are remnants of populations that once supported larger, more fecund, migratory forms.

2.2 Marine Phase

Anadromous bull trout forage and mature in the nearshore marine habitats on the Washington coast and in Puget Sound. The marine and estuarine residency period for bull trout is poorly understood. Thorpe's (1994) review found little evidence in the literature that the estuary was used for physiological adjustment or as a refuge from predation, but he did find clear evidence of a trophic advantage to estuarine residency (abundant prey). While in the estuary, native char can grow very quickly. Subadults grow from 20 to 40 mm per month and reach a length of 250 to 350 mm before their upstream migration in late summer and early fall (Kraemer 1994). During their marine residency, subadults from Dolly Varden populations on Vancouver Island gained 74 mm and adults gained 45 mm in length (Smith and Slaney 1979).

Kraemer (1994) speculated that the distribution of native char in marine waters may be closely tied to the distribution of bait fish and coincident with their spawning beaches. Char from Puget Sound have been found to prey on surf smelt, Pacific herring, Pacific sand lance, pink salmon smolts, chum salmon smolts, and a number of invertebrates (Kraemer 1994). The Quinault Indian Nation documented smelt as a prey item for native char in the Queets River. Kraemer (as cited in Nightingale and Simenstad 2001) observed that native char in estuaries typically foraged in water less than 3 meters deep and were often seen foraging in water less than 0.5 meters deep.

Anadromous migrations of bull trout have been studied in Rivers of the Olympic Peninsula in Washington. Radio-tagged bull trout from the Hoh River have migrated out into the marine

environment and then back into a number of other coastal drainages, including the Queets, and Quinault Rivers, and have showed complex movement patterns within and between rivers (Brenkman and Corbett 2005). In Alaska and British Columbia, downstream migration of Dolly Varden occurs in spring and early summer and upstream migration occurs from late spring through early winter (ADFG 1963; Armstrong 1965; Smith and Slaney 1979). In southeast Alaska, Dolly Varden spent an average of 116 days in marine waters (Armstrong 1965). Armstrong (1965) also reported that Dolly Varden migrated directly to saltwater and did not backtrack or linger in the river.

Anadromous char undertake fairly extensive marine migrations. Anadromous Dolly Varden typically stay close to the shoreline, but sometimes move up to 30 miles off shore (e.g., ADFG 1963). Dolly Varden move extensive distances in salt water, and may enter freshwater streams that are far from their natal streams (DeCicco 1992; Thorpe 1994). Kraemer (1994) has documented fish in Puget Sound as far as 25 miles from their natal stream. Marking studies used to investigate migratory patterns of Dolly Varden in southeast Alaska found marked fish in 25 different stream systems as far as 72 miles from their natal stream (Armstrong 1965). About forty percent of the marked fish appeared to migrate to other streams during the winter, but most fish remained within tens of miles of their natal streams.

Nearshore marine habitats have been significantly altered by human development (PSWQAT 2000). Construction of bulkheads and other structures have modified the nearshore areas and resulted in habitat loss that has directly affected forage fish for bull trout. Other impacts to the marine environment include alterations to water quality resulting from fish pathogens, nutrients and toxic contaminants, urbanization, and stormwater runoff from basins that feed Puget Sound. Global changes in sea level and climate may also have more widespread ramifications on these habitats, and on the Puget Sound ecosystem as a whole (Klarin et al. 1990; Thom 1992).

2.3 Food Habits

Like many fish, different life stages of bull trout feed at different trophic levels. Adult bull trout are apex piscivores, and require a large prey base and home range. Adult and subadult migratory bull trout feed primarily on various trout and salmon species, whitefish (*Prosopium* spp.), yellow perch (*Perca flavescens*), and sculpin (*Cottus* spp.). Subadult and adult migratory bull trout move throughout and between basins in search of prey. Anadromous bull trout in the Coastal-Puget Sound DPS also feed on ocean fish such as surf smelt (*Hypomesus pretiosus*) and sandlance (*Ammodytes hexapterus*). Resident and juvenile bull trout prey on terrestrial and aquatic insects, macrozooplankton, amphipods, mysids, crayfish, and small fish (Wyman 1975; Rieman and Lukens 1979 in Rieman and McIntyre 1993; Boag 1987; Goetz 1989; Donald and Alger 1993). A recent study in the Cedar River Watershed of western Washington found bull trout diets also include aquatic insects, crayfish, and salamanders (Connor et al. 1997).

2.4 Reproductive Biology

Bull trout become sexually mature between 4 and 9 years of age, and may spawn in consecutive or alternate years (Shepard et al. 1984; Pratt 1992). Spawning typically occurs from August through December in cold, low-gradient 1st- to 5th-order tributary streams, over loosely compacted gravel and cobble having groundwater inflow (Shepard et al. 1984; Brown 1992; Rieman and McIntyre 1996; Swanberg 1997; MBTSG 1998; Baxter and Hauer 2000).

Surface/groundwater interaction zones, which are typically selected by bull trout for redd construction, have high dissolved oxygen, constant cold water temperatures, and increased macro-invertebrate production. Spawning sites frequently occur near cover (Brown 1992).

Hatching occurs in winter or early spring, and alevins may stay in the gravel for up to three weeks before emerging. The total time from egg deposition to fry emergence from the gravel may exceed 220 days.

Post-spawning mortality, longevity, and repeat-spawning frequency are not well known (Rieman and McIntyre 1996), but lifespans may exceed 10 to13 years (McPhail and Murray 1979; Pratt 1992; Rieman and McIntyre 1993). Adult adfluvial bull trout may live as long as 20 years, and may require as much as 20 months in the lake or reservoir habitat to facilitate adequate energy storage and gamete development before they return to spawn again (67 FR 71236).

Migratory bull trout are highly visible during spawning due to their large size and location in relatively small streams during periods of low flow. Channel complexity and cover are important components of spawning habitat to reduce both predation risk and potential for poaching.

3. Population Dynamics

Bull trout are considered to display complex metapopulation dynamics (Dunham and Rieman 1999). Size of suitable habitat patches appears to play an important role in the persistence of bull trout populations, along with habitat connectivity and human disturbance, especially road density. Analyses of spatial and temporal variation in bull trout redds indicates weak spatial clustering in patterns of abundance through time (Rieman and McIntyre 1996). Spatial heterogeneity in patterns of abundance was high, however, at a regional scale. This combination of patterns suggests that maintenance of stable regional populations may require maintenance of connected patches of high quality habitat where dispersal and demographic support can occur readily among patches (Rieman and McIntyre 1996).

The importance of maintaining the migratory life-history form of bull trout, as well as migratory runs of other salmonids that may provide a forage base for bull trout, is repeatedly emphasized in the scientific literature (Rieman and McIntyre 1993; MBTSG 1998; Dunham and Rieman 1999; Nelson et al. 2002). Isolation and habitat fragmentation resulting from migratory barriers have negatively affected bull trout by: (1) reducing geographical distribution (Rieman and McIntyre 1993; MBTSG 1998); (2) increasing the probability of losing individual local populations (Rieman and McIntyre 1993; MBTSG 1998; Nelson et al. 2002; Dunham and Rieman 1999); (3) increasing the probability of hybridization with introduced brook trout (Rieman and McIntyre 1993); (4) reducing the potential for movements in response to developmental, foraging, and seasonal habitat requirements (MBTSG 1998; Rieman and McIntyre 1993); and (5) reducing reproductive capability by eliminating the larger, more fecund migratory form from many subpopulations (MBTSG 1998; Rieman and McIntyre 1993). Therefore, restoring connectivity and restoring the frequency of occurrence of the migratory form will reduce the probability of local and subpopulation extinctions. Remnant populations, that lack connectivity due to elimination of migratory forms, have a reduced likelihood of persistence (Rieman and McIntyre 1993; Rieman and Allendorf 2001).

Lakes and reservoirs provide important refugia for bull trout. In general, lake and reservoir environments are relatively more secure from catastrophic natural events than stream systems (67 FR 71236). They provide a sanctuary for bull trout, allowing them to quickly rebound from temporary adverse effects to spawning and rearing habitat. For example, if a major wildfire burns a drainage and eliminates most or all aquatic life (a rare occurrence), bull trout sub-adults and adults that survive in the lake may return the following year to repopulate the burned drainage. This underscores the need to maintain migratory life forms and habitat connectivity in order to increase the likelihood of long-term population persistence.

4. Threats and Conservation Needs

Threats are factors that reduce a species' likelihood of survival and recovery and lead to listing under the Act. Conservation needs are ecological conditions necessary to sustain stable or increasing populations of listed species, and measures that will create these conditions. Conservation needs alleviate or reverse the effects of threats and contribute to increasing the likelihood of survival and recovery of listed species.

4.1 Reasons for Listing

Factors contributing to the decline of bull trout populations were described in the final rules for listing. They include restriction of migratory routes by dams and other unnatural barriers; forest management, grazing, and agricultural practices; road construction; mining; introduction of non-native species; and residential development resulting in adverse habitat modification, over-harvest, and poaching (Bond 1992; Thomas 1992; Rieman and McIntyre 1993; Donald and Alger 1993; WDFW 1997).

Extensive habitat loss and fragmentation of subpopulations have been documented for bull trout in the Columbia River basin and elsewhere within its range (Rieman and McIntyre 1993). Road construction, grazing, and agricultural practices in the Columbia River basin have degraded habitat conditions by contributing to elevated stream temperatures, increased sedimentation and channel embeddedness, and reductions in the extent of riparian vegetation. Mining activities have compromised habitat conditions by discharging waste materials into streams and diverting and altering stream channels. Residential development has threatened water quality by introducing domestic sewage and altering riparian conditions. Dams of all sizes (e.g., mainstem hydropower and tributary irrigation diversions) have severely limited migration of bull trout in the Columbia River basin. Competition from and hybridization with non-native trout are also considered threats to bull trout (USDI 1998; 1999).

Wildfire in the dry forests of the interior Columbia Basin also presents a substantive threat to bull trout populations. Although bull trout evolved with wildfire, and can benefit from it, fire suppression in some areas has altered fire regimes so drastically that they no longer resemble historic fire regimes in which bull trout evolved (Rieman et al. 1997b; Rieman and Clayton 1997; Gresswell 1999). Species that have narrow habitat requirements, such as bull trout, that inhabit degraded and fragmented aquatic systems are considered vulnerable to fire and fire-related disturbance (Dunham et al. 2003b). In this context, wildfire could threaten long-term persistence of bull trout because it exerts selection pressures different than those that produced the phenotypes and genotypes present today.

4.2 New Threats

No new threats since listing have been specifically identified at the range-wide scale, but previously identified threats, or new threats at the local scale, may not have been fully appreciated. Examples include the proposed introduction of northern pike (*Esox lucius*) as a sport fish in Montana and expansion of the range of whirling disease (*Myxobolus cerebralus*).

4.3 Conservation Needs

Conservation needs are measures necessary to redress the threats that led to the listing of a species. As described in the "habitat" sections above, the habitat conservation needs of bull trout are often generally expressed as the need to provide the four "Cs"; cold, clean, complex, and connected habitat. Cold stream temperatures, clean water quality that is relatively free of sediment and contaminants, complex channel characteristics, including abundant large wood and undercut banks, and large patches of such habitat that are well connected by unobstructed migratory pathways are all needed to promote long-term conservation of bull trout.

In addition to habitat conservation needs, other needs are associated with sustaining population dynamics. These conservation needs include: (1) maintain and restore multiple, interconnected populations in diverse habitats across the range; (2) preserve the diversity of life-history strategies; and (3) maintain genetic and phenotypic diversity across the range. Each of these needs is described below in more detail. These conservation needs apply to bull trout at multiple scales ranging from the coterminous listing down to local populations.

4.3.1 *Interconnected Populations*. Maintaining multiple bull trout populations distributed and interconnected throughout their current range will also provide a mechanism for spreading the risk of extinction from stochastic events (Rieman and McIntyre 1993; Rieman and Allendorf 2001; Spruell et al. 1999; Healey and Prince 1995; Hard 1995). Bull trout still occur widely, but in reduced numbers, across most portions of their historical range. Within this broad distribution, significant declines and local extinctions have occurred. Current patterns in distribution and other empirical evidence indicate that further declines and local extinctions are likely (Rieman et al. 1997a; Spruell et al. 2003; Rieman and Allendorf 2001; Dunham and Rieman 1999). Maintenance of widespread and interconnected populations improves the chances that declining populations can be "rescued" from extinction by immigrants from more robust populations, or if local extinctions occur, that recolonization will follow.

Preservation of interconnected populations and multiple life histories enable bull trout to persist through natural disturbance events, such as large fires. Bull trout evolved under historic fire regimes in which disturbance to streams from forest fires resulted in a mosaic of diverse habitats. However, forest management and fire suppression over the past century have increased homogeneity of terrestrial and aquatic habitats, increasing the likelihood of large, intense forest fires in some areas. Because the most severe effects of fire on native fish populations can be expected where populations have become fragmented by human activities or natural events, an effective strategy to ensure persistence of native fishes in habitats susceptible to large fires may be to restore aquatic habitat structure and life-history complexity of populations in these areas (Gresswell 1999).

The spatial diversity and complexity of aquatic habitats strongly influence the effects of large disturbances on salmonids (Rieman and Clayton 1997). For example, Rieman et al. (1997b) studied bull trout and redband trout (*Oncorhynchus mykiss*) responses to large, intense fires that burned three watersheds in the Boise National Forest in Idaho. Although the fires were the most intense on record, there was a mix of severely burned to unburned areas left after the fires. Fish were apparently eliminated in some stream reaches, whereas others contained relatively high densities of fish. Within a few years after the fires, after areas within the watersheds had experienced debris flows, fish became reestablished in many reaches. In some instances, fish densities were higher than those present before the fires even in streams that were not burned (Rieman et al. 1997b). These responses were attributed to spatial habitat diversity that supplied refuge areas for fish during the fires, and the ability of bull trout and the redband trout to move among stream reaches. For bull trout, the presence of migratory fish within the system was also important (Rieman and Clayton 1997; Rieman et al. 1997b).

In terms of conserving bull trout, the appropriate strategy to reduce the risk of fires on bull trout habitat is to emphasize the restoration of watershed processes that create and maintain habitat diversity, provide bull trout access to habitats, and protect or restore migratory life-history forms of bull trout. Both passive (e.g., encouraging natural riparian vegetation and floodplain processes to function appropriately) and active (e.g., reducing road density, removing barriers to fish movement, and improving habitat complexity) actions offer the best approaches to protect bull trout from the effects of large fires.

4.3.2 *Life-History Diversity.* Bull trout populations exhibit multiple life-history forms, including migratory forms, throughout the range of the species (Rieman and McIntyre 1993). Migratory forms appear to develop when habitat conditions allow movement between spawning and rearing streams and larger rivers or lakes, where foraging opportunities may be enhanced (Frissell 1997). For example, multiple life-history forms (e.g., resident and fluvial) and multiple migration patterns have been noted in the Grande Ronde River (Baxter 2002). Parts of this river system have retained habitat conditions that allow free movement between spawning and rearing areas and the mainstem of the Snake River. Such multiple life-history strategies help to maintain the stability and persistence of bull trout populations in the face of environmental changes. Migratory bull trout may enhance persistence of metapopulations due to their high fecundity, large size, and dispersal across space and time, which promotes recolonization should resident populations suffer a catastrophic loss (Frissell 1997; Rieman and McIntyre 1993; MBTSG 1998).

4.3.3 *Genetic and Phenotypic Diversity.* Genetic diversity promotes both short-term fitness of populations and long-term persistence of a species by increasing the likelihood that the species is able to survive changing environmental conditions. This beneficial effect can be displayed both within and among populations. Within a genetically diverse local population of bull trout, different individuals may have various alleles that confer different abilities to survive and reproduce under different environmental conditions (Leary et al. 1993; Spruell et al. 1999; Hard 1995). If environmental conditions change due to natural processes or human activities, different allele combinations already present in the population may be favored, and the population may persist with only a change in allele frequencies. A genetically homogeneous population that has lost variation due to inbreeding or genetic drift may be unable to respond to environmental change and be extirpated. The prospect of local extirpation highlights the importance of genetic

diversity among local populations. Recolonization of locations where extirpations have occurred may be promoted if immigrants are available that possess alleles that confer an advantage in variable environmental conditions. Extending this reasoning to the entire range of the species, reduction in rangewide genetic diversity of bull trout through the loss of local populations can reduce the species ability to respond to changing conditions, leading to a higher likelihood of extinction (Rieman and McIntyre 1993; Leary et al. 1993; Spruell et al. 1999; Hard 1995; Rieman and Allendorf 2001).

Barriers to migration are an important factor influencing patterns of genetic variability in bull trout (Spruell et al. 2003; Costello et al. 2003). Although barriers increase the vulnerability of isolated populations to stochastic factors, they also insulate these populations from the homogenizing effects of gene flow. If isolated populations were founded by ancestors with rare alleles, genetic drift, unimpeded by gene flow, can lead to fixation of these rare alleles. Subsequent downstream migration from these isolated populations may be important in maintaining the evolutionary potential of metapopulations, because they provide inputs of genetic diversity (Costello et al. 2003).

The amount of genetic variation necessary for a population to adapt to a changing environment can be estimated using the concept of effective population size (N_e). Effective population size is the average number of individuals in a population which are assumed to contribute genes equally to the succeeding generation. Effective population size provides a standardized measure of the amount of genetic variation that is likely to be transmitted between generations within a population.

Specific benchmarks for bull trout have been developed concerning the minimum N_e necessary to maintain genetic variation important for short-term fitness and long-term evolutionary potential. These benchmarks are based on the results of a generalized, age-structured, simulation model, called VORTEX (Miller and Lacy 1999), used to relate effective population size to the number of adult bull trout spawning annually under a range of life histories and environmental conditions (Rieman and Allendorf 2001). Using the estimate that N_e for bull trout is between 0.5 and 1.0 times the mean number of adults spawning annually, Rieman and Allendorf (2001) concluded that (1) an average of 100 adults spawning each year would be required to minimize risks of inbreeding in a population, and (2) an average of 1,000 adults is necessary to maintain genetic variation important for long-term evolutionary potential. This latter value of 1,000 spawners may also be reached with a collection of local populations among which gene flow occurs.

Bull trout populations tend to show relatively little genetic variation within populations, but substantial divergence among populations (e.g., Spruell et al. 2003). For example, Spruell et al. (1999) found that bull trout at five different spawning sites within a tributary drainage of Lake Pend Oreille, Idaho, were differentiated based on genetic analyses (microsatellite DNA), indicating fidelity to spawning sites and relatively low rates of gene flow among sites. This type of genetic structuring indicates limited gene flow among bull trout populations, which may encourage local adaptation within individual populations (Spruell et al. 1999; Healey and Prince 1995; Hard 1995; Rieman and McIntyre 1993).

Current information on the distribution of genetic diversity within and among bull trout populations is based on molecular characteristics of individual genes. While such analyses are extremely useful, they may not reflect variability in traits whose expression is dependent on interactions among many genes and the environment (Hard 1995, Reed and Frankham 2001; but see Pfrender et al. 2000). Therefore, the maintenance of phenotypic variability (e.g., variability in body size and form, foraging efficiency, and timing of migrations, spawning, and maturation) may be best achieved by conserving populations, their habitats, and opportunities for the species to take advantage of habitat diversity (Healey and Prince 1995; Hard 1995).

Local adaptation may be extensive in bull trout because populations experience a wide variety of environmental conditions across the species' distribution, and because populations exhibit considerable genetic differentiation. Thus, conserving many populations across their range is essential to adequately protect the genetic and phenotypic diversity of bull trout (Hard 1995; Healey and Prince 1995; Taylor et al. 1999; Rieman and McIntyre 1993; Spruell et al. 1999; Leary et al. 1993; Rieman and Allendorf 2001). If genetic and phenotypic diversity is lost, changes in habitats and prevailing environmental conditions could increase the likelihood of bull trout suffering reductions in numbers, reproductive capacity, and distribution.

Based on this information about the life history and conservation needs of bull trout, the Service concludes that each subpopulation or local population is an important genetic, phenotypic, and geographic component of its respective interim recovery unit. Adverse effects that compromise the persistence of a bull trout subpopulation or local population can reduce the distribution, as well as the phenotypic and genetic diversity of the unit.

4.4 Recovery Planning

Recovery plans developed by the Service typically contain the most detailed articulation of the conservation needs of listed species. The goal of the draft recovery plan for bull trout is to ensure the long-term persistence of self-sustaining, complex interacting groups (or multiple local populations that may have overlapping spawning and rearing areas) of bull trout distributed across the species' native range.

The recovery of bull trout will depend on the reduction of the adverse effects from dams, logging, agricultural practices, road building, urbanization, fisheries management, and by remedying legacy effects from past activities. Other general conservation needs described in the draft recovery plan, but not mentioned in the preceding paragraphs, include:

- Prevent and reduce negative effects of nonnative fishes and other nonnative taxa on bull trout
- Establish fisheries management goals and objectives compatible with bull trout recovery, and implement practices to achieve those goals
- Characterize, conserve, and monitor genetic diversity and gene flow among local populations of bull trout (USFWS 2002).

Literature Cited for Appendix A

ADFG (Alaska Department of Fish and Game). 1963. Investigations of anadromous Dolly Varden populations in the Lake Eva-Hanus Bay drainages, southeastern Alaska. Dingell-Johnson Project Report, 1962-63, Vol. 4.

Allendorf, F.W. and N. Ryman. 2002. The role of genetics in population viability analysis. Pages 50-85 *in* S.R. Beissinger and D.R. McCullough (eds).Population Viability Analysis. The University of Chicago Press, Chicago, IL.

Armstrong, R.H. 1965. Some migratory habits of the anadromous Dolly Varden *Salvelinus malma* (Walbaum) in southeastern Alaska. Alaska Department of Fish and Game. Research Report No. 3. Juneau, Alaska. 36 p.

Baxter, C.V. 2002. Fish Movement and Assemblage Dynamics in a Pacific Northwest Riverscape. Ph.D. Dissertation, Oregon State University, Corvallis, OR. 174 pp.

Baxter, C.V., and F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and the selection of spawning habitat by bull trout (*Salvelinus confluentus)*. Canadian Journal of Fisheries and Aquatic Sciences. 57: 1470-1481.

Baxter, J.S.D., and J.D. McPhail. 1997. Diel microhabitat preferences of juvenile bull trout in an artificial stream channel. North American Journal of Fisheries Management 17:975-980.

BioAnalysts, Inc., 2004. Movement of Bull Trout in the Mid-Columbia River and Tributaries, 2001-2004. Report prepared for Chelan, Douglas, and Grant PUDs.

Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski and J.R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. *In* Streamside management: forestry and fishery interactions. E.O. Salo and T.W. Cundy, Editors., Univ. Washington, Institute of Forest Resources : 143-190.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirement of salmonids in streams. Pages 83-138. In: Influences of forest and rangeland management on salmonid fishes and their habitats. Editor: Meehan WR. American Fisheries Society Special Publication 19.

Boag, T.D. 1987. Food habits of bull char (*Salvelinus confluentus*), and rainbow trout (*Salmo gairdneri*), coexisting in the foothills stream in northern Alberta. Canadian Field-Naturalist 101(1): 56-62.

Bonar, S. A., Divens, M. and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout/Dolly Varden. Research Report RAD97-05. Washington Department of Fish and Wildlife, Olympia, Washington. 48 pp.

Bond, C.E. 1992. Notes on the nomenclature and distribution of the bull trout and the effects of human activity on the species. Pages 1-4 *In*: Howell, P.J. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.

Bonneau, J. L. and D. L. Scarnecchia 1996. Distribution of juvenile bull trout in a thermal gradient of a plunge pool in Granite Creek, Idaho. Transactions of the American Fisheries Society 125(4): 628-630.

Brenkman, S. J. and S. C. Corbett. 2005. Extent of anadromy in bull trout and implications for conservation of a threatened species. North American Journal of Fisheries Management 25(3):1073-1081.

Brewin P.A. and M. K. Brewin. 1997. Distribution Maps for Bull Trout in Alberta. Pages 206-216 *in:* Mackay, W.C., M.K. Brewin and M. Monita, editors. Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Calgary, Alberta, Canada.

Brown, L.G. 1992. On the zoogeography and life history of Washington native char Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). Washington Department of Wildlife, Fisheries Management Division Report. Olympia, Washington.

Bryant, M.D. 1983. The role and management of woody debris in West Coast salmonid nursery streams. North American Journal of Fisheries Management 3:322-330.

Buchanan, D. M. and S. V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pages 1-8 *in*: Mackay, W.C., M.K. Brewin and M. Monita, editors. Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Calgary, Alberta, Canada.

Buckman, R.C., W.E. Hosford, and P.A. Dupee. 1992. Malheur River Bull Trout Investigations. Pages 45-47 in Howell, P.J. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout *Salvelinus confluentus* (Suckley), from the American northwest. Calif. Fish and Game 64:139-174.

Cederholm, C.J. and L.M. Reid. 1987, Impact of Forest Management on Coho Salmon (*Oncoryhynchus isutch*) Populations of the Clearwater River, Washington: a Project Summary. Pages 373-398 in Salo, E.O., and T.W. Cundy, editors. Streamside Management: Forestry and Fishery Interactions. University of Washington Institute of Forest Resources contribution 57.

Connor, E., D. Reiser, K. Binkley, D. Paige, and K. Lynch. 1997. Abundance and distribution of an unexploited bull trout population in the Cedar River Watershed, Washington. Pages 403-411 *in* Mackay, W.C., M.K. Brewin, and M. Monita, editors. Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Costello, A. B., T. E. Down, S. M. Pollard, C. J. Pacas, and E. B. Taylor. 2003. The influence of history and contemporary stream hydrology on the evolution of genetic diversity within species: An examination of microsatellite DNA variation in bull trout, Salvelinus confluentus (Pisces: Salmonidae). Evolution 57(2):328-344.

Craig, S.D. and R.C. Wissmar. 1993. Habitat Conditions Influencing a Remnant Bull Trout Spawning Population, Gold Creek, Washington. (draft report) Fisheries Research Institute, University of Washington. Seattle, WA.

Crane, P.A., L.W. Seeb, and J.E. Seeb. 1994. Genetic relationships among *Salvelinus* species inferred from allozyme data. Canadian Journal of Fisheries and Aquatic Science 51:182-197.

DeCicco, A.L. 1992. Long-distance movements of anadromous Dolly Varden between Alaska and the U.S.S.R. Arctic 45(2): 120-123.

Dolloff, C.A. 1986. Effects of stream cleaning on juvenile coho salmon and Dolly Varden in southeast Alaska. Transactions of the American Fisheries Society 115: 743-755.

Donald, D.B. and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Dunham, J. B. and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9(2): 642-655.

Dunham, J. B., B. Rieman, and G. Chandler. 2003a. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894-904.

Dunham, J. B., M. K. Young, R. E. Greswell, and B. E. Rieman. 2003b. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions. Forest Ecology and Management 178(1-2):183-196.

Dunham, J.B. and G.L. Chandler. 2001. Models to predict suitable habitat for juvenile bull trout in Washington State. Final report to U.S. Fish and Wildlife Service, Lacey, WA.

Dunham, J., B. Rieman, and G. Chandler. 2001. Development of field-based models of suitable thermal regimes for Interior Colombia Basin salmonids. Interagency agreement #00-IA-11222014-521, Final report to EPA, Seattle WA.

Elliott, S.T. 1986. Reduction of a Dolly Varden population and macrobenthos after removal of logging debris. Transactions of the American Fisheries Society 115:392-400.

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.v Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production: a paradox. Pages 98-142 in Salo, E.O., and T.W. Cundy, editors. 1987. Streamside management: forestry and fishery interactions. University of Washington Institute of Forest Resources Contribution 57.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Science 63(4): 133-143.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetical Research 66:95-107.

Franklin, I.A. 1980. Evolutionary changes in small populations. Pages 135-150 *in*: Soulé M. and B.A. Wilcox (eds). Conservation Biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, MA.

Franklin, I.R. and R. Frankham. 1998. How large must populations be to retain evolutionary potential? Animal Conservation 1:69-70.

Frissell, C.A. 1997. A spatial approach to species viability: Conservation of fishes in the Columbia River Basin. Biological Station Open File Report Number 101-97. Flathead Lake Biological Station, University of Montana, Polson, MT.

Frissell, C.A. 1999. An ecosystem approach to habitat conservation for bull trout: groundwater and surface water protection. Open File Report Number 156-99. Flathead lake Biological Station, The University of Montana, Polson, MT.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*, literature review. Willamette National Forest, Eugene, Oregon.

Goetz, F. 1994. Distribution and juvenile ecology of bull trout (*Salvelinus confluentus*) in the Cascade Mountains. Masters Thesis. Oregon State University, Corvallis, OR.

Graham, P. J., Shepard, B. B., and Fraley, J. J. 1981. Use of stream habitat classifications to identify bull trout spawning areas in streams. Pages 186-190 *in* N. B. Armantrout. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society. Portland, Oregon.

Gresswell, R.E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society 128:193-221.

Grewe, P.M., N. Billington, and P.D.N. Hebert. 1990. Phylogenetic relationships among members of *Salvelinus* inferred from mitochondrial DNA divergence. Canadian Journal of Fisheries and Aquatic Science 47:984-991.

Haas, G.R., and J.D. McPhail. 1991. Systematics and distributions of Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Canadian Journal of Fisheries and Aquatic Sciences 48:2191-2211.

Hard, J. 1995. A quantitative genetic perspective on the conservation of intraspecific diversity. American Fisheries Society Symposium 17:304-326.

Healy, M.C. and A. Prince. 1995. Scales of variation in life history tactics of Pacific salmon and the conservation of phenotype and genotype. American Fisheries Society Symposium 17:176-184.

Hedrick, P.W. and S. T. Kalinowski. 2000. Inbreeding depression in conservation biology. Annual Review of Ecology and Systematics 31:139-162.

Hindes, R. 1994. Watershed characterization and ranking report. Wenatchee River watershed ranking project. Chelan County Conservation District. 151 pp. plus appendix.

House, R.A., and P.L. Boehne. 1987. The effect of stream cleaning on salmonid habitat and populations in a coastal Oregon drainage. Western Journal of Applied Forestry 2:84-87

Jakober, M. 1995. Autumn and winter movement and habitat use of resident bull trout and westslope cutthroat trout in Montana. M.S. Thesis, Montana State University, Bozeman, MT.

Kanda, N., R., Leary, and F. W. Allendorf. 1997. Population genetic structure of bull trout in the upper Flathead River drainage. Pages 299-308 *in* W.C. Mackay, M.K. Brewin and M. Monita (eds). Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Calgary, Alberta, Canada.

Kelly-Ringel, B. 1997. Analysis of Fish Populations in Icicle Creek, Trout Creek, Jack Creek, Peshastin Creek, Ingalls Creek, and Negro Creek, Washington 1994-1995. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington.

Klarin, P.N., K.M. Branch, M.J. Hershman and T.F. Grant. 1990. An analytical review of state and federal coastal management Systems and Policy Responses to Sea Level Rise. Report to Washington State Department of Ecology, Olympia, Washington.

Kraemer, C. 1994. Some observations on the life history and behavior of the native char, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) of the North Puget Sound Region. Wash. Dept. of Wildlife. Draft.

Leary, R. F., F. W. Allendorf, and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology 7(4): 856-865.

Lisle, T.E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Whales Island, Southeast Alaska. North American Journal of Fisheries Management 6: 538-550.

Lynch, M. and R. Lande. 1998. The critical effective size for a genetically secure population. Animal Conservation 1:70-72.

MBTSG (Montana Bull Trout Scientific Group). 1998. The relationship between land management activities and habitat requirements of bull trout. Report prepared for the Montana Bull Trout Restoration Team, Helena, MT.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate the effects of forestry activities on stream in the Pacific Northwest and Alaska. Region 10, U.S. Environmental Protection Agency. EPA 90/9-91-001.

McCullough, D., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of technical literature examining the physiological effects of temperature on salmonids. Issue paper 5. Prepared as part of the EPA Region 10 water quality criteria guidance development project. Seattle, WA.

McMahon, F., A. Zale, J. Selong, and R. Barrows. 2001. Growth and survival temperature criteria for bull trout. Annual report 2000 (year three). National Council for Air and Stream Improvement. 34 p.

McPhail, J. D. and R. Carveth. 1992. A foundation for conservation: the nature and origin of the freshwater fish fauna of British Columbia. Fish Museum, Department of Zoology, University of British Columbia. Vancouver, British Columbia, Canada.

McPhail, J.D. and J.S.D. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Fisheries management report no. 104. University of British Columbia. Vancouver, B.C.

McPhail, J.D. and C. Murray. 1979. The early life history of Dolly Varden *(Salvelinus malma)* in the upper Arrow Lakes. Report to the British Columbia Hydro and Power Authority and Kootenay Department of Fish and Wildlife. University of British Columbia, Department of Zoology and Institute of Animal Resources, Vancouver, B.C. (As referenced in USDI, 1997).

Miller, P.S. and R.C. Lacy. 1999. VORTEX: a stochastic simulation of the extinction process. Version 8 user's manual. Conservation breeding specialists group (SSC/IUCN), Apple Valley, MN.

Mongillo, P. E. 1993. The distribution and status of bull trout/Dolly Varden in Washington State. Washington Department of Wildlife. Fisheries Management Division, Report 93-22. Olympia, Washington. 45 pp.

Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43: 1521-1533.

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and AlaskaBrequirements for protection and restoration. NOAA Coastal Ocean Program Decision Analysis Series Number 7. NOAA Coastal Office, Silver Springs, Maryland. 156 p.

Nelson, M., T. McMahon, and R. Thurow. 2002. Decline of the migratory form in bull charr, *Salvelinus confluentus*, and implications for conservation. Environmental Biology of Fishes, 64:321-332, 2002.

Nightingale, B., and C. A. Simenstad. 2001. Overwater structures: marine issues. White Paper, Res. Proj. T1803, Task 35, Wash. State Dept. Transportation, Washington Sate Trans. Center (TRAC), Seattle, WA. 133 pp + appendices.

Peterson, J., Dunham, J., Howell, P., Thurow, R., and S. Bonar. 2001. Draft report: Protocol for determining bull trout presence. 51 pp.

Pfrender, M.E., Spitze, K., Hicks, J., Morgan, K., Latta, L., and M. Lynch. 2000. Lack of concordance between genetic diversity estimates at the molecular and quantitative-trait levels. Conservation Genetics 1:263-269.

Phillips, R.B., S.L. Sajdak, and M.J. Domanico. 1995. Relationships among charrs based on DNA sequences. Nordic Journal of Freshwater Research 71:378-391.

Pleyte, Kay A., Shan D. Duncan, and Ruth B. Phillips. 1992. Evolutionary relationships of the salmonid fish genus *Salvelinus* inferred from DNA sequences of the first internal transcribed spacer (ITS 1) of ribosomal DNA. Molecular Phylogenetics and Evolution, 1(3):223-230.

Pratt, K.L. 1992. A review of bull trout life history. *In*: P. J. Howell and D. V. Buchanan (eds.). Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon. Pp. 5-9.

Pratt, K.L. and J.E. Huston. 1993. Status of bull trout (*Salvelinus confluentus*) in Lake Pend Oreille and the lower Clark Fork River: (draft report) Prepared for the WWPC, Spokane, WA.

PSWQAT (Puget Sound Water Quality Action Team). 2000. 2000 Puget Sound Update: Seventh Report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team. Olympia, Washington. Literature References.

Quigley, T.M. and S.J. Arbelbide, tech. editors. 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins: volume III. General Technical Report PNW- GTR-405. U. S. Department of Agriculture, Forest Service, and U. S. Department of Interior, Bureau of Land Management

Ratcliff, D.E. 1992. Bull Trout Investigations in the Metolius River- Lake Billy Chinook System. Pages 37-44 in Howell, P.J. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon (As referenced in USDI, 1997).

Reed, D. H., and R. Frankham. 2001. How closely correlated are molecular and quantitative measures of genetic variation? A meta-analysis. Evolution 55:1095-1113.

Riehle, M.D. 1993. Metolius Basin Water Resources Monitoring, Progress Report 1988-1992. U.S. Department of Agriculture, Forest Service, Deschutes National Forest, Bend, Oregon. (As referenced in USDI 1997).

Riehle, M., W. Weber, A.M. Stuart, S.L. Thiesfeld and D.E. Ratliff. 1997. Progress report of the multi-agency study of bull trout in the Metolius River system, Oregon. *In*: Friends of the Bull Trout Conference Proceedings, May 5-7, 1994. W.C. MacKay, M.D. Brewin, M. Monita, Co-editors. The Bull Trout Task Force. Calgary, Alberta. Pages 137-144.

Rieman, B.E. and F.W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21:756-764.

Rieman, B., and J. Clayton. 1997. Wildfire and native fish: Issues of forest health and conservation of sensitive species. Fisheries 22(11):6-15.

Rieman, B.E. and J. R. Lukens. 1979. Lake and reservoir investigation: Priest Lake creel census. Job Completion Report. Project F-73-R-1, Subproject III, Study, I, Job I. Boise, ID. Idaho Department of Fish and Game. 105 pp.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U. S. Forest Service, Intermountain Research Station. General Technical Report INT-302.

Rieman, B.E. and J.D. McIntyre. 1996. Spatial and temporal variability in bull trout redd counts. North American Journal of Fisheries Management 16:132-141.

Rieman, B.E. and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124 (3): 285-296.

Rieman, B.E., D.C. Lee and R.F. Thurow. 1997a. Distribution, status and likely future trends of bull trout within the Columbia River and Klamath Basins. North American Journal of Fisheries Management 17(4): 1111-1125.

Rieman, B., Lee, D., Chandler, G. and D. Myers. 1997b. Does wildfire threaten extinction for salmonids? Responses of redband trout and bull trout following recent large fires on the Boise National Forest. Pp. 47-57 *in*: J. Greenlee (ed.), Proceedings B Fire effects on rare and endangered species and habitats conference, Nov. 13 - 16, 1995. Coeur d'Alene, Idaho.

Rode, M. 1990. Bull trout, *(Salvelinus confluentus)* Suckley, in the McCloud River: status and recovery recommendations. Administrative Report Number 90-15. California Department of Fish and Game, Sacramento, CA.

Selong, J. H., T. E. McMahon, A. V. Zale, and F. T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026-1037.

Sexauer, H. M. and P. W. James. 1993. A survey of the habitat use by juvenile and pre-spawning adult bull trout, *Salvelinus confluentus*, in four streams in the Wenatchee National Forest. Ellensburg, WA, Central Washington University.

Shepard, B., S.A. Leathe, T.M. Weaver, and M.D. Enk. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake, and impacts of fine sediment on bull trout recruitment. Proceedings of the Wild Trout III Symposium. Yellowstone National Park, Wyoming. On file at: Montana Department of Fish Wildlife, and Parks, Kalispell, Montana.

Slaney, P.A., T.G. Halsey, and A.F. Tautz. 1977. Effects of forest harvesting practices on spawning habitat of stream salmonids in the Centennial Creek watershed, British Columbia. British Columbia Ministry of Recreation and Conservation, Fish and Wildlife Branch, Fisheries management Report 73, Victoria.

Smith, H.A. and P.A. Slaney. 1979. Age, growth, survival and habitat of anadromous Dolly Varden (*Salvelinus malma*) in the Keogh River, British Columbia. British Columbia Ministry of Environment. Fisheries Management Report. Vancouver, B.C. 56 p.

Soulé, M.E. 1987. Viable Populations for Conservation. Cambridge University Press, Cambridge, UK. 206pp.

Spence, B. C., G. A. Lomnicky, R. M. Hughs, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. (Available from the National Marine Fisheries Service, Portland, Oregon.).

Spruell, P., Hemmingsen, A.R., Howell, P.J., Kanda, N., and F.W. Allendorf. 2003. Conservation genetics of bull trout: Geographic distribution of variation at microsatellite loci. Conservation Genetics 4:17-29.

Spruell, P., B. Rieman, K. Knudsen, F. Utter and F. Allendorf. 1999. Genetic population structure within streams: microsatellite analysis of bull trout populations. Ecology of Freshwater Fish 1999: 8: 114-121.

Spruell, P., and F. Allendorf. 1997. Nuclear DNA analysis of Oregon bull trout. Final report to the Oregon Department of Fish and Wildlife. Division of Biological Sciences, University of Montana.

Suttle, K. B., M.E. Power, J. M. Levine, and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications 14(4):969-974.

Swanberg, T. 1997. Movements of and habitat use by fluvial bull trout in the Blackfoot River, Montana. Transactions of the American Fisheries Society. 126: 735-746.

Taylor, E., S. Pollard and D. Louie. 1999. Mitochondrial DNA variation in bull trout (*Salvelinus confluentus*) from northwestern North America: implications for zoogeography and conservation. Molecular Ecology 8:1155-1170.

Thom, R.M. 1992. Accretion rates of low intertidal salt marshes in the Pacific Northwest. Wetlands 12:147-156.

Thomas, G. 1992. Status of bull trout in Montana. Report prepared for Montana Department of Fish, Wildlife and Parks, Helena, Montana.

Thorpe, J.E. 1994. Salmonid Fishes and the Estuarine Environment. Estuaries. 17 (1A): 76-93.

USDA (United States Department of Agriculture), USDC (United States Department of Commerce), and USDI (United States Department of Interior). 2004. Analytical Process for Developing Biological Assessments for Federal Actions Affecting Fish Within the Northwest Forest Plan Area. Forest Service, National Marine Fisheries Service, Bureau of Land Management, and Fish and Wildlife Service. Portland, OR. 53 pp.

USDI (United States Department of Interior). 1997. Endangered and threatened wildlife and plants; proposal to list the Klamath River population segment of bull trout as an endangered species and Columbia River population segment of bull trout as a threatened

species. Fish and Wildlife Service. June 13, 1997. Federal Register 62(114): 32268-32284.

USDI (United States Department of Interior). 1998. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Klamath River and Columbia River Distinct Population Segments of Bull Trout. June 10, 1998. Federal Register 63(111):31647-31674.

USDI (United States Department of Interior). 1999. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the bull trout in the coterminous United States; Final Rule. November 1, 1999. Federal Register 64(210):58910-58933.

USFWS (United States Fish and Wildlife Service). 2002. Bull trout (*Salvelinus confluentus*) draft recovery plan. U. S. Fish and Wildlife Service, Portland, Oregon.

USFWS (United States Fish and Wildlife Service). 2000. Bull trout occurrence and habitat selection. Western Washington Fish and Wildlife Office, Lacey, Washington. October 23, 2000.

USFWS (United States Fish and Wildlife Service). 1999a. Endangered and threatened wildlife and plants; determination of threatened status for bull trout in the coterminous United States; final rule. Notice of intent to prepare a proposed special rule pursuant to section 4(d) of the Endangered Species Act for the bull trout; proposed rule. Fish and Wildlife Service. November 1, 1999. Federal Register Vol. 64:58910.

Volk, E.C. 2000. Using otolith strontium to infer migratory histories of bull trout and Dolly Varden from several Washington state rivers. Submitted to Olympic National Park in fulfillment of Contract # 2550041. Washington Department of Fish and Wildlife, Olympia.

Waples, R.S. 2002. Definition and estimation of effective population size in the conservation of endangered species. Pages 147-168 *in* S.R. Beissinger and D.R. McCullough (eds). Population Viability Analysis. The University of Chicago Press, Chicago, IL.

Waters, Thomas F. 1995. *Sediment in Streams: Sources, Biological Effects, and Control.* American Fisheries Society Monograph 7.

Watson, G. and T. W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales. North American Journal of Fisheries Management 17:237-252.

WDFW (Washington Department of Fish and Wildlife). 1997. Washington Department of Fish and Wildlife hatcheries program. Operations program - Lewis river complex for January 1, 1997 to December 31,1997. Washington Department of Fish and Wildlife, Olympia, WA.

Weaver, T. M. 1992. Status of the adfluvial bull trout populations in Montana's Flathead drainage: the good, the bad, and the unknown. P. 449 *In*: Mackay, W. C., M. K. Brewin, M. Monita (eds.) Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Weaver, T.M. and R.G. White. 1985. Coal Creek Fisheries monitoring study No. III. Quarterly progress report. U.S. forest Service, Montana State Cooperative Fisheries Research Unit, Bozeman, MT.

Williams, R. N., R. P. Evans, and D. J. Shiozawa. 1995. Mitochondrial DNA diversity in bull trout from the Columbia River basin. Pages 283-297 *in* W.C. Mackay, M.K. Brewin, and M. Monita (eds). Friends of the Bull Trout Conference Proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Calgary, Alberta, Canada.

Wyman, K. H. 1975. Two unfished salmonid populations in Lake Chester Morse. M.S. Thesis, University of Washington. Seattle, Washington.

Ziller. 1992. Distribution and relative abundance of bull trout in the Sprague River subbasin, Oregon. *In*: Howell, P.J. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Personal Communications

J. De La Vergne. 2002. U.S. Fish and Wildlife Service, Fish and Wildlife Biologist, Wenatchee, Washington

J. Muck. 2010. Unpublished series of sediment analysis tools including a literature review, process for analyzing sedimentation effects, and table of monitoring data and studies from projects that generated increased sedimentation.

C. Kraemer. 2002. Washington Department of Fish and Wildlife, Olympia, Washington

APPENDIX B: Projects subject to prior Section 7 consultation in the Teanaway Watershed that may have had impacts on bull trout or their habitat.

Project Name	FWS Reference	Date
Teanaway River Bridge Protection	1-9-98-FC-0004	August 26, 1998
Teanaway Bulkhead and Temporary Rock Placement	13260-2006-TA-0217	October 27, 2005
Way Creek Trail Improvements	13260-2006-I-0120	April 7, 2006
Fulks – North Fork Teanaway Bank Restoration	13260-2006-I-0133	May 16, 2006
BPA Irrigation Installations in Kittitas County	13260-2006-I-0215	May 31, 2006
BPA Pump Screening	13260-2007-I-0069	March 22, 2007
Teanaway Fuelbreaks Informal	13260-2009-I-0073	April 28, 2009
Teanaway Fuelbreaks BO	13260-2009-F-0074	June 15, 2009
Teanaway PIT Tag Reader	13260-2010-I-0053	May 5, 2010
Teanaway EQUIP Restoration	13260-2010-I-0100	August 18, 2010
Kittitas Consv. Dist. – Teanaway Fish Passage	13260-2011-F-0004	October 25, 2010

Note: This list does not include projects that were determined to have "no effect" on bull trout, or projects that were covered under the Programmatic for Selected Forest Management Activities (USFWS ref. 1-9-2003-I-W0102 and 1-09-2005-I-W0172). This programmatic covers only activities that result in "not likely to adversely affect" determinations, based on conformance with specific design criteria.

APPENDIX C. Crosswalk between the Bull Trout Matrix and Bull Trout Critical Habitat Primary Constituent Elements

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March 31, 2011

The purpose of this document is to provide a consistent means for analyzing baseline conditions and project effects to both the bull trout and designated critical habitat for the bull trout using the Matrix of Pathways and Indicators.

The Matrix of Pathway Indicators (Matrix or MPI) for bull trout is used to evaluate and document baseline conditions and to aid in making effect determinations for proposed projects (USFWS 1999). The Matrix analysis incorporates one population pathway and six habitat pathways which represent different features or functions of populations and habitat that can be affected by projects. These features and functions are characterized by measurable indicators of population performance and habitat conditions (4 population indicators and 19 physical habitat indicators). Analysis of these indicators provides a systematic approach for evaluating the existing baseline condition and potential project impacts, using metrics meaningful to bull trout.

Designated critical habitat for the bull trout (75 FR 63898) includes nine primary constituent elements (PCEs). These PCEs correspond to physical, chemical, and biological features included in the Matrix habitat indicators. Table 1 shows the correspondence between the PCEs for bull trout critical habitat and the Matrix habitat indicators. The following paragraphs describe each of the nine PCEs and the Matrix indicators (named using italics font) relevant to them.

1. **Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.**

   The analysis of *floodplain connectivity* considers the hydrologic linkage of off-channel areas with the main channel and maintenance of wetland function and riparian vegetation and succession supported by overbank flow. Floodplain and riparian areas provide hydrologic connectivity for springs, seeps, groundwater upwelling and wetlands and contribute to the maintenance of the water table. The *sediment* and *substrate embeddedness* indicators describe the level of fine sediment in the gravel which affects hyporheic flow. Fine sediment fills interstitial spaces making the movement of water through the substrate less efficient. The *chemical contamination/nutrients* and *temperature* indicators evaluate the water quality of groundwater. The *off-channel habitat* indicator suggests how much off-channel habitat is available, and generally side-channels are connected to adjacent channels via subsurface water. The *change in peak/base flows* indicator considers whether or not peak flow, base flow, and flow timing are comparable to an undisturbed watershed of similar size, geology, and geography. Peak flows, base flows, and flow timing are directly related to subsurface water connectivity and the degree to which soil compaction has decreased infiltration and increased surface runoff. The *drainage network increase* and *road density and location*

indicators assess the influence of the road and trail networks on subsurface water connectivity. If there is an increase in drainage network and roads are located in riparian areas, it is likely that subsurface water is being intercepted before it reaches a stream. If groundwater is being intercepted then it is likely that water quality is being degraded through increased temperatures, fine sediment, and possibly chemical contamination. *Streambank condition* addresses groundwater influence through an assessment of stability. The *disturbance history* indicator evaluates disturbance across the watershed and provides a picture of how management may be affecting hydrology. The *riparian conservation areas* indicator determines whether riparian areas are intact and providing connectivity. If riparian areas are intact it is much more likely that springs, seeps, and groundwater sources are able to positively affect water quality and quantity.

2. **Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.**

The *physical barriers* indicator provides the most direct assessment of this PCE. Analysis of this indicator includes consideration of whether man-made barriers within the watershed allow upstream and downstream passage of all life stages at all flows. However, some indicators further evaluate physical impediments and others evaluate the biological or water quality impediments that may be present. The *temperature*, *sediment, substrate embeddedness,* and *chemical contamination/nutrients* indicators assess whether other barriers may be created, at least seasonally, by conditions such as high temperatures, high concentrations of sediment, or contaminants. The *average wetted width/maximum depth ratio* indicator can help identify situations in which water depth for adult passage may be a problem. A very high average wetted width/maximum depth value may indicate a situation where low flows, when adults migrate, are so spread out that water depth is insufficient to pass adults. The *change in peak/base flows* indicator can help determine if change in base flows have been sufficient to prevent adult passage during the spawning migration. The *persistence and genetic integrity* indicator addresses biological impediments by evaluating negative interactions (e.g., predation, hybridization, and competition) with other species.

3. **An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.**

None of the indicators directly address this PCE, but a number of them address it indirectly. The *sediment* and *substrate embeddedness* indicators document the extent to which substrate interstitial spaces are filled with fine sediment. Interstitial spaces provide important habitat for aquatic macroinvertebrates, sculpin, and other substrate-oriented prey which are important food sources for bull trout. The *chemical contamination/ nutrients* indicator evaluates the level to which a stream is contaminated by chemicals or has a high level of nutrients. Chemicals and nutrients greatly affect the type and diversity of aquatic invertebrate communities present in a water body. The *large woody debris* and *pool frequency and quality* indicators assess habitat complexity. High stream habitat

complexity is associated with diverse and abundant macroinvertebrate and fish prey. The *off-channel habitat* and *floodplain connectivity* indicators document the presence of off-channels which are generally more productive than main channels. Off channel areas are important sources of forage, particularly for juveniles. The *streambank condition* and *riparian conservation areas* indicators both shed light on the very basis of the food base of a stream. Vegetation along streambanks and in riparian areas provide important habitat for terrestrial macroinvertebrates that can fall into the water as well as sources of nutrient inputs that support aquatic invertebrate production.

4. **Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.**

   Several indicators address this PCE directly. The *sediment* and *substrate embeddedness* indicators provide insight into how complex substrates are within a stream by documenting percent fines and embeddedness. As percent fines and embeddedness increase, substrate complexity decreases. The *large woody debris* indicator provides an excellent picture of habitat complexity. The indicator rates the stream based on the amount of in-channel large woody debris. Habitat complexity increases as large wood increases. The *pool frequency and quality* and *large pools* indicators address habitat complexity by rating the stream based on the frequency of pools and their quality. Habitat complexity increases as the number of pools and their quality increase. The *off-channel habitat* indicator directly addresses complexity associated with side channels. The indicator is rated based on the amount of off-channel habitat, cover associated with off-channels, and flow energy levels. *Average wetted width/maximum depth ratio* is an indicator of channel shape and pool quality. Low ratios suggest deeper, higher quality pools. The *streambank condition* and *riparian conservation areas* indicators both shed light on the complexity of river and stream shorelines. Vegetation along streambanks and in riparian areas provides important habitat complexity and channel roughness. The *streambank condition* indicator also provides information about the capacity of an area to produce undercut banks, which can be a very important habitat feature for bull trout. The *floodplain connectivity* indicator addresses complexity added by side channels and the ability of floodwaters to spread across the floodplain to dissipate energy and provide access to high-flow refugia for fish. The *road density and location* indicator addresses complexity by identifying if roads are located in valley bottoms. Roads located in valley bottoms reduce complexity by eliminating vegetation and replacing complex habitats with riprap or fill, and often confine the floodplain. The *disturbance regime* indicator documents the frequency, duration, and size of environmental disturbance within the watershed. If scour events, debris torrents, or catastrophic fires are frequent, long in duration, and large, then habitat complexity will be greatly reduced.

5. **Water temperatures ranging from 2 to 15 °C (36 to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form;**

geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.

The *temperature* indicator addresses this PCE directly. The indicator rates streams according to how well temperatures meet bull trout requirements. Other matrix indicators address temperature indirectly. The *off-channel habitat* and *floodplain connectivity* indicators address how well stream channels are hydrologically connected to off-channel areas. Floodplains and off-channels are important to maintaining the water table and providing connectivity to the channel for springs, seeps, and groundwater sources which contribute cool water to channels. The *average wetted width/maximum depth ratio* indicator also corresponds to temperature. Low width to depth ratios indicate that channels are narrow and deep with little surface area to absorb heat. The *streambank condition* indicator documents bank stability. If the streambanks are stabilized by vegetation rather than substrate then it is likely that the vegetation provides shade which helps prevent increases in temperature. The *change in peak/base flows* indicator evaluates flows and flow timing characteristics relative to what would be expected in an undisturbed watershed. If base flow has been reduced, it is likely that water temperature during base flow has increased since the amount of water to heat has decreased. The *road density and location* and *drainage network increase* indicators documents where roads are located. If roads are located adjacent to a stream then shade is reduced and temperature is likely increased. Roads also intercept groundwater and can reduce this cooling influence, as well as discharge typically warmer stormwater. The *disturbance history* indicator describes how much of the watershed has been altered by vegetation management and therefore indicates how much shade has been removed. The *riparian conservation areas* indicator addresses stream shade which keeps stream temperatures cool. The presence of *large pools* may provide thermal refugia when temperatures are high.

6. **In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout will likely vary from system to system.**

The *sediment* and *substrate embeddedness* indicators directly address this PCE. These indicators evaluate the percent fines within spawning areas and the percent embeddedness within rearing areas. The *streambank condition* and *riparian conservation areas* indicators indirectly address this PCE by documenting the presence or lack of potential fine sediment sources. If streambanks are stable and riparian conservation areas are intact then there is a low risk of introducing fine sediment from bank erosion. Also, the *floodplain connectivity* indicator indirectly addresses this PCE. If the stream channel is connected to its floodplain, then there is less risk of bank erosion during high flows because stream energy is reduced as water spreads across the floodplain. The *increase in drainage network* and *road density and location* indicators assess the effects of roads on the channel network and hydrology. If the drainage network has significantly increased

as a result of human-caused disturbance or road density is high within a watershed and roads are located adjacent to streams, then it is likely that in-channel fine sediment levels will be elevated above natural levels. The *disturbance regime* indicator documents the nature of environmental disturbance within the watershed. If the disturbance regime includes frequent and unpredictable scour events, debris torrents, and catastrophic fire, then it is likely that fine sediment levels will be elevated above background levels. A consideration for all indicators directly or indirectly influencing this PCE is that it is desirable to achieve an appropriate balance of stable areas to provide undercut banks and eroding areas that are sources for recruiting new spawning gravels. Too little sediment in a stream can also be detrimental.

7. **A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.**

The *change in peak/base flows* indicator addresses this PCE directly by documenting the condition of the watershed hydrograph relative to an undisturbed watershed of similar size, geology, and geography. There are several indicators that address this PCE indirectly. The *streambank condition* indicator documents bank stability. If the streambanks are stabilized by vegetation rather than substrate then it is likely that the streambank can store water during moist periods and releases that water during dry periods which contributes to water quality and quantity. The *floodplain connectivity* indicator is relevant to water storage within the floodplain which directly affects base flow. Floodplains are important to maintaining the water table and providing connectivity to the channel for springs, seeps, and groundwater sources which contribute to water quality and quantity. The *increase in drainage network* and *road density and location* indicators assess the influence of the road and trail networks on hydrology. If there is an increase in drainage network and roads are located in riparian areas, it is likely is being intercepted and quickly routed to a stream which can increase peak flow. The *disturbance history* indicator evaluates disturbance across the watershed and provides a picture of how management may be affecting hydrology; for example, it may suggest the degree to which soil compaction has decreased infiltration and increased surface runoff. The *riparian conservation areas* indicator determines whether riparian areas are intact, functioning, and providing connectivity. If riparian areas are intact it is much more likely that springs, seeps, and groundwater sources are able to positively affect water quality and quantity.

8. **Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.**

This PCE is closely related to PCE 7, with PCE 8 adding a water quality component (i.e., there is a high level of overlap in indicators that apply to both PCEs 7 and 8). The *temperature* and *chemical contamination/nutrients* indicators directly address water quality by comparing water temperatures to bull trout water temperature requirements, and documenting 303(d) designated stream reaches. Several other indicators indirectly address this PCE by evaluating the risk of fine sediment being introduced that would

result in decreased water quality through increased turbidity. The *streambank condition* and *riparian conservation areas* indicators indirectly address this PCE by documenting the presence or lack of potential fine sediment sources. If streambanks are stable and riparian conservation areas are intact then there is a low risk of introducing fine sediment from bank erosion. Also, the *floodplain connectivity* indicator indirectly addresses this PCE. If the stream channel is connected to its floodplain, then there is less risk of bank erosion during high flows because stream energy is reduced as water spreads across the floodplain. *Average wetted width/maximum depth ratio* is an indication of water volume, which indirectly indicates water temperature, (i.e., low ratios indicate deeper water, which in turn indicates possible high-flow refugia). This indicator in conjunction with *change in peak/base flows* is an indicator of potential water quality and quantity deficiencies, particularly during low flow periods. The *increase in drainage network* and *road density and location* indicators assess the effects of roads on the channel network and hydrology. If the drainage network has significantly increased as a result of human-caused disturbance or road density is high within a watershed and roads are located adjacent to streams, then it is likely that suspended fine sediment levels will be elevated above natural levels. If roads are located adjacent to a stream then shade is reduced and temperature is likely increased. Roads also intercept groundwater and can reduce this cooling influence, as well as discharge typically warmer stormwater. The *disturbance regime* indicator documents the nature of environmental disturbance within the watershed. If the disturbance regime includes frequent and unpredictable scour events, debris torrents, and catastrophic fire, then it is likely that turbidity levels will be elevated above background levels.

9. **Sufficiently low levels of occurrence of nonnative predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.**

   The only indicator that directly addresses this PCE is the *persistence and genetic integrity* indicator. This indicator addresses the likelihood of predation, hybridization, or displacement of bull trout by competitive species. The *temperature* indicator can provide indirect insights about whether conditions are conducive to supporting "warm water" species.

Appendix C Table 1. Relationship of the Matrix Indicators to the Primary Constituent Elements of Bull Trout Crit Habitat

Pathways (bold) and Indicators	**PCE 1 - Springs, Seeps, Groundwater**	**PCE 2- Migratory Corridors ***	**PCE 3 - Abundant Food Base**	**PCE 4 - Complex Habitats**	**PCE 5 - Temperature**	**PCE 6 - Substrate**	**PCE - 7 Hydrograph**	**PCE 8 - Water Quality/ Quantity**	**PCE 9 - Nonnative Species***
Water Quality									
Temperature	X	X			X			X	X
Sediment	X	X	X	X		X			
Chemical Contamination/Nutrients	X	X	X					X	
Habitat Access									
Physical Barriers		X							
Habitat Elements									
Substrate Embeddedness	X	X	X	X		X			
Large Woody Debris			X	X					
Pool Frequency and Quality			X	X					
Large Pools				X	X				
Off-Channel Habitat	X		X	X	X				
Refugia	X	X	X	X	X	X	X	X	X
Channel Conditions and Dynamics									
Wetted With/Max. Depth Ratio		X		X	X			X	
Streambank Condition	X		X	X	X	X	X	X	
Floodplain Connectivity	X		X	X	X	X	X	X	
Flow/Hydrology									
Changes in Peak/Base Flows	X	X			X		X	X	
Drainage Network Increase	X				X	X	X	X	
Watershed Conditions									
Road Density and Location	X			X	X	X	X	X	
Disturbance History	X				X		X		
Riparian Conservation Areas	X		X	X	X	X	X	X	
Disturbance Regime				X		X		X	

* = PCE is also related to the population pathway, *persistence and genetic integrity* indicator