WRIA 44/50

FINAL PHASE 2 BASIN ASSESSMENT

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Prepared for

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SIGNATURE

This report and Pacific Groundwater Group's work contributing to this report were reviewed by the undersigned and approved for release.

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1.0 EXECUTIVE SUMMARY

This assessment was prepared for the Water Resource Inventory Area (WRIA) 44/50 Planning Unit. Foster Creek Conservation District is the lead agency for this Planning Unit.

This assessment was prepared under the auspices of the Watershed Management Act. The Act was designed to allow local entities to develop watershed management plans for entire watersheds. The framework this process is based on consists of geographic areas known as Water Resource Inventory Areas (WRIAs), or watersheds. Locally established Planning Units assess each WRIA's water supply and use, and then recommend strategies for satisfying water supply needs while recognizing the need to preserve habitat for fish.

The purpose of this technical assessment is to characterize the water resources of WRIAs 44 and 50, to provide a scientific basis for the Planning Unit when developing a watershed plan, and to provide state agencies with natural resources information for use when making management, permit, and funding decisions.

This assessment is an ongoing process and was prepared with the data available at the time of printing. Data collection will continue and addenda will be issued as necessary. These addenda may change the conclusions and recommendations presented here.

1.1 GEOGRAPHY

WRIAs 44 and 50 comprise a total of 2,043 square miles of the Columbia Plateau and include parts of Grant, Douglas, and Okanogan counties. The Columbia River borders the two WRIAs on the north and west. The WRIAs contain nine sub-basins (see **Figure 1-1**), including eight creeks of significant size: Foster Creek, Corbaley/Pine Canyon Creek, Sand Canyon Creek, Rock Island Creek, Coyote Creek, McCartney Creek, Rattlesnake Creek, and Douglas Creek/Moses Coulee.

Almost half of the land within the two WRIAs is used for non-irrigated cropped lands, and another quarter is used for grazing. Approximately five percent of the land in the WRIAs is irrigated agriculture, and is primarily used for the production of hard and soft fruit and forage crops. The irrigated agricultural lands are located primarily along the Columbia River corridor, adjacent upland areas, and Moses Coulee Basin.

1.2 HYDROLOGY

Precipitation that falls in WRIAs 44 and 50 flows toward the Columbia River, either as groundwater or as surface water. On the way, water may also return to the atmosphere through evaporation or transpiration. Many of the streams lose water to the underlying aquifer as they enter the Columbia River basin because the sediments become coarser (more permeable) and thicker, so that the water is able to percolate underground.

In general, water can flow easily between the Columbia River and the surrounding alluvium. Therefore, a large percentage of groundwater pumped from the alluvial aquifer and from within a short distance of the Columbia likely originates from the Columbia. Much of the water use in the WRIAs, either for irrigation or domestic use, occurs along the banks of the Columbia River. Therefore, much of the water used within the WRIAs likely comes from outside of the WRIAs (the Columbia River), not from precipitation falling within the WRIAs. To address this issue within this report, the two WRIAs have been divided into two geographic areas: the Columbia River Region (corridor) and the Inland Region. The Columbia River Region is generally defined as all sections within one mile of the Columbia River. The Inland Region includes all the rest of the land area within the two WRIAs. Due to the complexity of water management decisions in the Columbia River Region, the Planning Unit has been precluded from making water management recommendations in the Columbia River Region. Therefore this study has focussed on the Inland Region.

1.3 WATER QUANTITY

Assessment of water quantity was implemented by gathering data to estimate water availability and studying the number and type of water rights that exist in WRIAs 44 and 50.

1.3.1 WATER AVAILABILITY

Total estimated surface water and groundwater leaving the Inland area is 260,000 af/yr. An estimated 30 percent of the water discharges as surface water and 70 percent discharges as groundwater.

Total estimated water usage including irrigation, water systems, and private wells is 57,000 af/yr for the Columbia and Inland Regions combined. This water usage is about 25 percent of the water discharging from the two WRIAs. This usage appears high because much of the water use is immediately adjacent to the Columbia River (about 85 percent), and the source of that water is the Columbia River itself, not water discharging from the two WRIAs.

Total water use in the Inland Region is approximately 6,383 af/yr, which is an estimated 2.5 percent of the water discharging from the two WRIAs. Ninety percent of the water use within the Inland Region occurs mostly for irrigation in Moses Coulee sub-basin. Another seven percent is accounted for by the combined usage from the Douglas Creek, Foster Creek, Rock Island/Sand Canyon/Pine Canyon, and the Upper Columbia Swamp Creek sub-basins.

Water balances were performed by sub-basin to identify areas of high demand relative to water availability. A water balance compares the amount of water available to the amount of water used within the WRIAs. In this case, water available means all of the water leaving the sub-basin or WRIAs within a given year. However, not all of this water is actually available for use due to water quality, economic, or environmental issues.

On an annual basis, the largest area of use compared to water leaving the sub-basin is in the Moses Coulee sub-basin (6 percent), followed by the Upper Columbia Swamp Creek (3 percent), and Douglas Creek (1 percent). However, most of the water is used during the irrigation season, when only a portion of the annual water budget is available. Therefore, water use was also compared to water available during the April to October irrigation season. During that time period, water use was 11 percent in the Moses Coulee sub-basin, 5 percent in the Upper Columbia Swamp Creek sub-basin, and 1 percent in the Douglas Creek sub-basin.

1.3.2 WATER RIGHTS

Total water rights (including water certificates, permits, and claims) were assessed for the two WRIAs. It should be noted that many of the water rights have likely fallen into disuse and therefore do not reflect current use. Water rights are predominantly for irrigation use, both adjacent to the Columbia River (64%) and in the Inland Region (90%). Water rights along the Columbia River account for approximately 90 percent of the allocated water in WRIAs 44 and 50.

Water discharging from the sub-basin was compared with allocated water rights (certificates and permits) to assess what percentage of water available annually is actually allocated. Moses Coulee has the largest percent of available groundwater allocated (24 percent) and the largest percentage of surface water allocated (8.0 percent). Upper McCartney (13 percent), Douglas Creek (12 percent), and Lower McCartney (10 percent), all have greater than 10 percent of available groundwater allocated. All other basins have less than 10 percent of groundwater and surface water allocated.

Water rights, including claims, were also compared to the amount of water available during the irrigation season, when most of the water is used. Basins that have 50 percent or more available water allocated are groundwater allocations in Upper McCartney Creek (63 percent) and Moses Coulee (50 percent) and surface water allocations in Upper McCartney Creek (105 percent).

1.4 HABITAT CONDITIONS

The Panning Unit originally identified six streams were with potentially accessible habitat for anadromous fish use. Detailed Level 1 surveys were initiated in each of these streams. The presence of anadromous salmonid fish use in two streams, Foster Creek and Rock Island Creek, was confirmed during 2001. Two other streams, Sand Canyon Creek and Moses/Douglas Creeks, had sporadic observations of anadromous salmonid use from the late 1970s to the early 1990s. The remaining two streams, Pine Canyon

Creek and Blue Grade Draw, have the potential for anadromous fish access and at least temporary use. There was no evidence of current anadromous fish use in these four other streams.

In general, the topography and landforms near streams as they enter the Columbia River limit the potential available fish habitat for spawning and rearing in the WRIAs. The high plateau of the Columbia Basin breaks off sharply near the canyon walls of the Columbia River, creating: (1) very steep, cascading stream reaches through inter-gorge canyons, and (2) extensive alluvial floodplains at the mouths of these streams as the channel gradient flattens near the Columbia River. Most of the streams are seasonal flood channels; some have perennial or intermittent springs. Low summer streamflows often flow below the surface of the alluvial fans (i.e., dry river bed conditions), restricting fish access and rearing capabilities.

Blockages to the upstream and downstream migration of anadromous fish species were found in all of the streams surveyed to date. Blockages included dams, irrigation control structures, road culverts, and dry stream channels. It is likely that many of the dry stream channels are natural conditions that have existed historically in the WRIAs. Further Level 2 study effort regarding historical flow regimes, especially in Moses Coulee, will be necessary to complete this assessment.

Stream channels in the WRIAs are strongly controlled by the underlying geologic parent materials, which vary between basins. The most highly erosive soils were found in the Foster Creek and Sand Canyon Creek basins where parent soils include glacial drift/lacustrine sediments and silty slump materials, respectively. As a result, these two streams exhibit heavy channel loading of fine sediments. Foster and Sand Canyon Creeks apparently do not have the transport capacity to clear the small material from the streambed. The sediment deposition in these creeks is overwhelming the capacity of the streams to transport fines downstream. The other streams surveyed in the WRIAs support greater capacity to transport sediment loads compared to Foster and Sand Canyon Creeks.

Most of the watercourses in WRIAs 44 and 50 reviewed during 2001 are small in relation to the size of their valley. This suggests that historical forces were much greater than the current drainage systems' ability to form channels. This aspect will be important when recommending instream flow levels.

1.5 WATER QUALITY

All waters of WRIAs 44 and 50 are classified as Class A - Excellent, waters of the state (WAC 173-201a). None of the waterbodies draining interior lands are currently listed as 303(d) water quality limited waters and the Washington State Department of Ecology is not currently planning to perform Total Maximum Daily Load (TMDL) studies in WRIAs 44 and 50.

Because the available information on water quality parameters in streams throughout the WRIAs was sparse, a screening-level assessment was necessary. Therefore, spot water quality measurements were collected and continuous temperature gauges were installed in selected streams at the beginning of Level 1. Water quality data collection continued through Level 2 studies. The results indicate that water temperatures vary considerably in streams in WRIAs 44 and 50 based on weather patterns, stream discharge, channel shape, shading, and the influence of groundwater flows. Rock Island and Pine Canyon Creeks support relatively cool summer water temperatures that are favorable for rearing fish as a result of significant springs and groundwater inflows. Foster and Douglas Creeks supported warm (but not necessarily detrimental) temperatures to cold-water fish production during the drought conditions in 2001. Conversely, Blue Grade Draw and perhaps Sand Canyon Creek are too warm for summer rearing fish production. The peak daily temperatures throughout the months of July and August exceeded lethal conditions in Blue Grade Draw and sub-lethal conditions in Sand Canyon Creek.

Monitored dissolved oxygen (DO) levels in portions of the anadromous fish streams were generally very favorable, indicating appropriate levels of re-aeration in the flowing streams. The only area of concern exists in Foster Creek, where there is evidence of abundant late summer plant growth and large fluctuations in DO concentrations. Measured DO concentrations ranged from 6.63 to 11.82 milligrams per liter (mg/L) (representing 67 to 130% saturation). A combination of both over- and undersaturated DO levels may indicate oxygen dynamics that are related to plant respiration and photosynthesis.

All pH levels monitored during the summer of 2001 were within the Class A water quality criterion between 6.5 and 8.5 pH units (+/- 0.5 pH units). The waters are generally alkaline in nature, which is typical of arid and semi-arid conditions. Douglas and Foster Creeks were the most alkaline, while Rock Island and Pine Canyon Creeks were neutral to slightly alkaline. Blue Grade Draw and Sand Canyon Creek water reflected irrigation withdrawals from the Wenatchee River system. They were neutral in pH and supported relatively soft waters compared to other local streams.

Conductivity is a relative measure of mineralization in streams. Inland streams of the Columbia River Basin under arid and semi-arid conditions often consist of more mineralized waters as a result of evaporation and soil erosion. Groundwater inputs also generally increase stream mineralization. Data collected during the summers of 2001 and 202 indicate conductivity exceeding 140 µmhos/cm in Coyote Creek, 200 µmhos/cm in Rock Island Creek, 300 µmhos/cm in Douglas Creek, 500 µmhos/cm in McCarteney and Rattlesnake Creeks, 600 µmhos/cm in Pine Canyon Creek, and 800 µmhos/cm in Foster Creek. The high numbers in Foster Creek likely express a combination of groundwater input, high levels of soil erosion, and high evaporation (open canopy). Conductivity levels of the irrigation return flows in Blue Grade Draw (30 to 50 µmhos/cm) and in Sand Canyon Creek (60 to 150 µmhos/cm) are uncharacteristically low in mineralization compared to local streams, reflecting the relatively soft waters from the Wenatchee River.

Measurements of nitrogen- and phosphorous-related compounds representing nutrient sources from flowing streams are generally unavailable, except in Douglas Creek. Dissolved components of these nutrients are available for plant uptake and, if excessive, they can stimulate abundant growths of attached periphyton and algae. An abundance of periphyton and algal masses have been observed in Foster Creek, suggesting that growing conditions are sufficient for fairly good development of aquatic plants.

The South Douglas Conservation District measured elevated levels of nitrate in shallow groundwater and surface waters in the headwater region of Douglas Creek in the late 1980s. As stream flows increased downstream, high nutrient levels were generally diluted to normal levels. The nitrate level (1.10 mg/L) in Douglas Creek at the BLM gauging station at RM 1.5 was similar to the mean value determined from 71 summer samples from regional streams and rivers with similar geology, physiography, vegetation, and climate (0.93 mg/L) (USEPA 2000). Dissolved and total phosphorous levels in Douglas Creek (0.090 and 0.110 mg/L, respectively) were almost identical to regional averages of 0.087 and 0.109 mg/L from 127 summer samples (USEPA 2000).

Very limited spot measurements of nutrients are available from Foster Creek. The nutrient concentrations measured were near average values reported by the United States Environmental Protection Agency (USEPA) for the region. The level of available information is too sparse to assess nutrient conditions in local streams. The only areas of nutrient concern noted were: (1) the high levels of nutrients in shallow groundwater and in surface waters of the Douglas Creek headwater region, and (2) the excessive levels of aquatic plant growth and the associated dissolved oxygen fluctuations observed in Foster Creek in 2001.

Screening level benthic macroinvertebrate sampling was performed at eleven sites in nine streams to assess stream health. Macroinvertebrate communities present suggest that a wide range of habitat conditions exist among the streams. The data indicate that Sand Canyon Creek and Blue Grade Draw contain a low density and diversity of macroinvertebrates and that the fauna is comprised entirely of short-lived taxa. The majority of the taxa exhibit burrowing habits that allow them to survive in temporary habitats when streamflows cease. The macroinvertebrate communities in the other four streams were more abundant and diverse and various macroinvertebrate groups were more evenly represented. Furthermore, the benthic fauna was comprised of short-lived and long-lived taxa with varying habits. The macroinvertebrate data imply that relatively good water quality and habitat conditions occur in the perennial flowing reaches of Douglas, upper Pine Canyon, Rock Island, Coyote, and McCartney Creeks. Habitat seems to be slightly impaired in Foster and West Foster Creek and, according to Ecology (1996), habitat is impaired compared to natural conditions in Sand Canyon, Blue Grade Draw, East Foster and Rattlesnake Creeks. Lower Moses Coulee and lower Pine Canyon creek are not conducive for benthic invertebrate production due to the lack of surface water stream flow throughout the year.

2.0 INTRODUCTION

Water Resource Inventory Areas (WRIAs) 44 and 50 encompass most of Douglas County and parts of Grant and Okanogan counties. WRIAs 44 and 50 are bordered by the Columbia River on the north and west. They contain 11 sub-watersheds (per USGS Hydrologic Unit Map) and eight creeks of significant size: Foster Creek, Corbaley/Pine Canyon Creek, Sand Canyon Creek, Rock Island Creek, Coyote Creek, McCartney Creek, Rattlesnake Creek, and Douglas Creek/Moses Coulee. In addition, there are numerous smaller creeks and lakes within the WRIAs.

Almost half of the land within the two WRIAs is used for non-irrigated cropped lands, and another quarter is used for grazing. Wheat is the principal crop, grown on about 90 percent of harvested croplands. Apples and cattle are also significant industries. Approximately five percent of the land in the WRIAs is irrigated agriculture, used for the production of hard and soft fruit and forage crops. Irrigated agricultural lands are located primarily along the Columbia River corridor, adjacent upland areas, and Moses Coulee Basin. Most of the remaining land area is characterized by forest and steppe shrub vegetation that provides diverse wildlife habitat.

The principal water users are the Douglas County PUD, Chelan County PUD, and a number of irrigators. Several irrigation districts in the WRIAs pump surface water from the Columbia River including the Greater Wenatchee Irrigation District, the Bridgeport Bar Irrigation District, and the East Wenatchee Irrigation District. The majority of water use is concentrated around the Columbia River and south-western Moses Coulee sub-basin.

Chinook salmon spawn and rear in the Columbia River and larger tributaries, while steelhead and coho utilize both the mainstem as well as the smaller tributaries.

2.1 PURPOSE AND SCOPE

The purpose of this assessment is to characterize the water resources of WRIAs 44 and 50, to provide a scientific basis for a watershed plan, and to provide State agencies with natural resources information to assist in making management, permit, and funding decisions. Specific items that define the scope of this assessment include:

- Tabulate water rights information by document type, sub-basin, and purpose of use.
- Describe available data relevant to surface water and characterize surface water resources.
- Estimate present water use by sub-basin.
- Forecast future water demands based on demographic factors countywide and the designated growth areas.
- Perform a water balance, comparing groundwater recharge to groundwater use.
- Perform a habitat assessment of the five major streams in WRIAs 44 and 50.
- Assess the water quality of the five major streams in WRIAs 44 and 50
- Install stream gauges in the five major streams and begin collection of streamflow data.

This assessment was completed for the Water Resource Inventory Area (WRIA) 44/50 Planning Unit. The WRIA 44/50 Planning Unit was formed under the auspices of the Watershed Planning Act (HB 2514; Chapter 90.82 RCW). Foster Creek Conservation District is the lead agency for the planning unit.

2.2 REGULATORY FRAMEWORK

The 1998 Legislature passed Engrossed Substitute House Bill 2514 (The Watershed Management Act) to provide a framework to collaboratively solve water related issues. This bill, along with the associated grants program, is designed to allow local citizens and local governments to join with tribes and state agencies to develop watershed management plans for entire watersheds. This framework is based on geographic areas known as Water Resource Inventory Areas (WRIAs), or watersheds. Locally established "planning units" are to assess each WRIA's water supply and use and recommend strategies for satisfying water supply needs. In addition, the opportunity is also provided for local planning units to address the closely related issues of improving water quality, protecting and enhancing fish and wildlife habitat, and, in collaboration with the Department of Ecology (Ecology), to set instream flows.

2.3 WATERSHEDS AND WRIAS

Natural resource agencies at the national, State, and local levels have increasingly adopted the concept of "watersheds" in their policy and programmatic approaches. At the most basic level, a watershed is a geographic area where any drop of rain will drain to a single body of water, such as a lake or river. A watershed can be as small as a basin that drains to a tiny creek, or as large as the Columbia River Basin. The important thing to recognize is that water resource issues such as water supply, water quality, and habitat for fish and wildlife are closely linked together within watersheds. What happens upstream affects what happens downstream (Economic and Engineering Services, Inc. 1999).

The Legislature embraced this watershed concept in passing the Watershed Management Act. However, in order to simplify its application within the State's existing water resources management structure, the law uses WRIAs as the organizing geographic unit. Under the law, planning must include either an entire WRIA, or more than one entire WRIA. There are 62 WRIAs in Washington State. Some of these are unitary river basins, in which all surface waters flow into a single river. Others are artificially defined segments of a basin, such as a "lower" and "upper" basin. Still others are actually assemblages of many distinct streams or rivers that never join together. The presence and movement of groundwater may roughly correspond with that of surface waters in a WRIA or the groundwater may behave very differently, depending on local conditions.

The geographic area contained in a WRIA rarely corresponds with political jurisdictions such as city or county boundaries. Most WRIAs include parts of two or more counties.

3.0 HYDROGEOLOGY AND GROUNDWATER FLOW

WRIAs 44 and 50 comprise a total of 2,043 square miles of the Columbia Plateau and include parts of Grant, Douglas, and Okanogan counties. The WRIAs may be further subdivided into nine sub-basins, as shown in **Figure 1-1**. These sub-basins were derived from the United States Geological Service (USGS) Hydrologic Units that depict surface water basins. These sub-basins may or may not correlate with groundwater basins. The sub-basins discharge into the Columbia River with three exceptions. The Douglas Creek and Lower McCartney Creek sub-basins discharge into the Moses Coulee sub-basin, and the Upper McCartney Creek sub-basin discharges into the Lower McCartney Creek sub-basin.

WRIAs 44 and 50 are predominantly underlain by the Miocene basaltic rocks of the Columbia River Basalt Group. In this area, the basalt sequence is generally 2,000 to 3,000 feet thick and has been divided, from oldest to youngest, into two main units. The Grande Ronde Basalt, which is the thickest, contains as many as 131 flows; the Wanapum Basalt, as many as 33 flows. Interbed deposits, often consisting of mud stones, siltstone, and sandstone, separate the two basalt formations and may also occur within the two formations.

Individual basalt flows in the Columbia River Basalt Group range from a few tens of feet to about 300 feet in thickness; the average thickness is about 100 feet. Some thick flows that are exposed in canyons and road cuts display extensive fracture patterns due to differential rates of cooling. The tops and the bottoms of flows are typically permeable because of rubble zones, vesicles, and fractures. These zones form the principal aquifers within the basalt. However, some of these open spaces are filled with clay minerals that decrease permeability. The central parts of most flows are dense and are less permeable. Openings caused by minor vertical cooling fractures provide some limited permeability in the central part of the flows.

The Ellensburg formation and other unconsolidated deposits overlie the basalts in many areas. These deposits are generally less than 50 feet thick on the plateau but may be as much as 200 feet thick on the banks of the Columbia and in Moses Coulee. The bedrock that underlies the Columbia River Basalt Group consists of pre-Miocene igneous, metamorphic, and consolidated sedimentary rocks.

3.1 HYDROLOGIC CONCEPTUAL MODEL

The two WRIAs are characterized by a semi-arid climate with average precipitation between 8 and 12 inches per year (Bartu, and Andonaegui, 2001). **Figures 3-1** through **3-5** show the typical shrub-steppe vegetative cover and some of the prominent hydrologic features.

Precipitation occurring within the WRIAs may run off directly to a stream, percolate to groundwater, or return to the atmosphere through evaporation or evapotranspiration. Groundwater and surface water move from topographically high margins of the plateau toward major surface drainages. There may be transfers of water between groundwater and streams as water moves towards the Columbia River. Many of the streams become groundwater as they enter the Columbia River basin because the alluvium becomes coarser (more permeable), thicker, and is more easily recharged by surface water.

In general, there is hydraulic connection between the Columbia River and the surrounding alluvium although a deeper aquifer also exists which is not in communication with the Columbia. Groundwater pumped from the shallow alluvial aquifer within a short distance of the Columbia likely originates from the Columbia. Groundwater pumped within a short distance of the Columbia likely captures water from the Columbia by inducing infiltration or intercepts ground water flowing toward the Columbia, depending on the physical setting. Much of the water use in the WRIAs, whether for irrigation or domestic use, occurs along the banks of the Columbia River. Therefore, much of the water used within the WRIAs likely comes from outside of the WRIAs and not from precipitation falling within the WRIAs. To address this issue within this report, the two WRIAs have been divided into two geographic areas: the Columbia River and the Inland areas. The Columbia River area is defined as all sections within approximately one mile of the Columbia River (**Figure 1-1**). The Inland Area comprises the remainder of the two WRIAs.

4.0 WATER RIGHTS

The State of Washington regulates groundwater and surface water withdrawals through a legal system of water allocations. There are four categories within the water rights process:

- Applications
- Permits
- Certificates
- Claims

The first step in the process is when an individual or entity submits an *application* to the Department of Ecology for the right to appropriate water for a stated beneficial use. Upon receiving an application for a water right, Ecology may issue a *permit* for the individual or entity to develop the water resource. Water right *certificates* are issued after the water withdrawal has been perfected (actually put to use) and the amount of use has been verified. Water right claims are discussed below.

Quantities of water allocations are not necessarily equal to quantities of water use. Allocations state the maximum quantities of withdrawal that are legally permitted. In many cases, the full extent of these permitted quantities has not been put to beneficial use and perfected, and a significant discrepancy exists between allocations and use. A distinction between allocation and use must be drawn in assessing the stress on the hydrologic system due to withdrawals. Therefore, actual use cannot be quantified using water allocation statistics, but may be judged by surveying the major water users and estimating the sum of minor users. Although total allocation may differ from actual use, total allocation remains a significant figure because it represents the maximum legally permitted withdrawal from the hydrologic system.

Water rights are issued permitted quantities of instantaneous and annual withdrawals. The instantaneous allocation (Qi) may be set to a standard, such as 0.02 cubic feet per second (cfs) or 10 gallons per minute (gpm) per acre for irrigation; it may be set to system design limitations; or it may be set per what the applicant has requested, if appropriate. Qi's are expressed in cfs for surface water and gpm for groundwater. The annual allocation (Qa) represents the maximum amount of water allowed within a year for a specified use or uses, and is expressed in af/yr. Research of water rights records indicates that for most permits/certificates, the Qa is not withdrawn continuously but is taken seasonally or sporadically at rates approaching the Qi.

4.1 CLAIMS

Water uses before 1917 (for surface water) or 1945 (for groundwater) pre-date the current system of water right allocation established under Ch 90.03 RCW and Ch 90.44 RCW. These uses may represent a valid water right if:

1. The water was first applied to beneficial use prior to the appropriate date;
2. The water has been used continuously to the present time; and
3. A claim for the use has been filed during one of four filing periods.

The first filing period for water right claims was created by the State Legislature and ran from July 1, 1969 through June 30, 1974; approximately 177,000 claims were filed statewide during this period.

A second short filing period was created by the legislature in 1979.

The third filing period created by the legislature ran from July 1, 1985 through September 1, 1985. During this filing, the claimant had to petition the Pollution Control Hearings Board (PCHB) for a certificate and make a showing to the PCHB regarding their water use before the claim would be accepted by Ecology.

The fourth and most recent filing period created by the legislature ran from September 1, 1997 through June 30, 1998.

Each of the filing periods had unique limitations and differences. A thorough understanding of these differences can only be gained by reading the various legislation that created/limited each of the filing periods. An example of these limitations is in the most recent filing period (9/1/97 through 6/30/98) which gave claims filed during this opening a priority date of the date when the statement of claim was filed with Ecology, even though the water use being claimed needed to start prior to 1917 for surface water or 1945 for groundwater for the claim to be valid.

Claims for one water use may have been registered multiple times during different filing periods. Claims do not necessarily represent a valid water right and Ecology does not have the authority to determine their validity except through a basin wide water right adjudication process that takes place in the County Superior Court. Ecology may make tentative determinations of the validity of claimed water rights when processing applications for change of a water right. Ecology's tentative determinations may be subject to change or reversal during the water right adjudication process. Much of the large irrigation water usage in WRIAs 44 and 50 is represented by water right claims.

4.2 EXEMPT WELLS

A special type of water resource allocation is the "exempt" water right. A formal application for a water right is not required for any combination of the following uses:

- Stock watering purposes
- Single or group domestic purposes up to 5,000 gallons per day (5.6 af/yr Qa)
- Industrial purposes up to 5,000 gallons per day
- Watering a lawn or noncommercial garden that is a half-acre or less in size

The allocation associated with exempt wells at the maximum allowable rate of withdrawal is potentially very significant. However, most exempt wells are likely to be used for single dwellings, and the actual amount of use associated with such an allocation is likely to be far below the maximum allowable use.

Since 1972, Ecology has required that water well reports (well logs) be submitted to the agency. The number of well logs on file with Ecology is an underestimate of the number of wells in the county because many water well report forms have not been submitted, the wells were installed before submittal of well logs was required, or the well log may have been lost from state files. A study comparing the number of wells and population (or number of wells and improved parcels) in Clark County showed that well logs on file with Ecology accounted for about 40 percent of the total population (or parcels) likely to be reliant on individual groundwater wells.

4.3 DATA SOURCES AND DATA REDUCTION

Water rights data for WRIAs 44 and 50 were obtained from Ecology's Water Rights Application Tracking System (WRATS) database. The data were reduced, using the following procedures:

- Denied applications, relinquished certificates, rejected claims, and canceled permits were removed from consideration.
- Duplicate water rights were removed.
- Water right changes were removed because quantity and place of use were not changed within the database, only priority date.
- Qa's were estimated based on multipliers recommended by Ecology. Estimates were made where the Qa values were missing but irrigated acres or numbers of domestic units were specified. Irrigated acres were multiplied by 3 af/yr, and domestic units were multiplied by the maximum allowable 5000 gallons per day.
- Water rights and allocations specified as non-consumptive, such as surface water rights for power generation, were not considered.
- Water rights with multiple sources in more than one section were divided among the sections.
- Reservoir rights were combined with surface water rights.

4.4 WATER RIGHTS ALLOCATIONS IN WRIAS 44 AND 50

All the allocated consumptive water rights (permits and certificates) in WRIAs 44 and 50 total approximately 240,786 af/yr (**Table 4-1**). Claims account for another 17,384,780 af/yr. However, this value represents only the 50 percent of the 2,265 claims in WRIAs 44 and 50 that have annual withdrawal amounts associated with them. Assuming the average Qa of the existing 50 percent is representative of those without Qa values, the total Qa for claims is approximately 35 million af/yr. However, many of these claims are likely no longer in use.

The requested Qa for all water right applications is 56,427 af/yr. However, the WRATS database typically does not list values of Qa for applications because Qa is generally determined during the permitting process. Therefore the total projected Qa is likely greater than 56,427 af/yr.

As presented in the Hydrogeologic Conceptual Model section of this report (Section 3.1), the WRIAs are divided into the area adjacent to the Columbia River and the Inland area. Water rights along the Columbia River account for approximately 90 percent of the allocated water in the two WRIAs (**Figures 4-1 and 4-2**). The majority of existing water right certificates and claims adjacent to the Columbia River are for surface water withdrawals. However, pending permits and applications are predominantly for groundwater withdrawals. This change suggests that water use is shifting from surface water to groundwater sources. In the Inland area, all categories are predominantly for groundwater.

The 1,008 well logs filed with the Department of Ecology in the WRIAs may use up to an estimated 5,645 af/yr, based on an allocation of 5,000 gallons per day. However, it is unlikely that domestic users would put their maximum permissible allocation to use because a single household uses approximately 460 gallons per day (Section 5.0). The estimated volume of the maximum ground water withdrawal authorized under the domestic exemption accounts for less than three percent of the allocation for all permits and certificates. However, in isolated areas such as Badger Mountain, exempt wells may account for a high percentage of water use.

The majority of the water rights allocations are for irrigation use, both adjacent to the Columbia River (64%) and in the Inland Area (90%). The second largest categories are fish propagation adjacent to the Columbia (20%) and domestic municipal Inland (4%). **Tables 4-2 and 4-3** show the breakdown of permits and certificates by purpose of use for the Columbia and Inland areas. Not all of the water rights in the WRATS database are listed in the database table of allocation by use. Therefore, the total allocated amount by use is less than other totals reported elsewhere in this report.

5.0 WATER USE

Estimates of water use in WRIAs 44 and 50 were calculated to identify areas of high demand. Water use was estimated from multiple sources, including:

- Annual water use per connection as reported by Mansfield and Waterville
- Directly reported numbers of hookups for public water systems (contained in the Washington State Department of Health SADIE database)
- Counts of well logs per section made by the Foster Creek Conservation District
- Number of irrigated acres provided by Douglas County

The amount of annual water use was divided by the number of connections to estimate the use per connection for the cities of Mansfield and Waterville. The average amount of water use per connection for the two cities is 670 and 367 gallons per day, respectively. A weighted average of 460 gallons per day per connection was used in calculations for all domestic wells and system connections.

The WDOH database contains information on the number of connections in each water system and the location of the sources used by the system. A water system is a source with more than one connection. Water systems are divided into Group A and B systems for regulatory purposes. Group A water systems have 15 or more residential connections or 25 or more people per day for 60 or more days per year.

If a system had sources in more than one section, the number of connections was divided evenly among the sections. Both residential and non-residential connections were assigned a usage of 460 gallons per day.

The well log database was used to estimate water usage by users with private wells. Data from this database were entered from well logs submitted by drillers to the Department of Ecology. Ecology began requiring drillers to submit well logs in 1972, so wells completed before 1972 are not included. Well logs were summed by section and multiplied by the annual usage per connection. Each private well was assumed to use 460 gallons per day.

Irrigation water use was estimated using a GIS coverage of irrigated acreage and multiplying by approximate usage per acre. Irrigated acreage is shown in **Figure 5-1**. Most of the irrigation water use is along the Columbia and was discounted from the water balance presented in Section 8.0. Irrigation along the Columbia is mostly for orchards, which use approximately three af/yr. Most other irrigation occurs in Moses Coulee, which is planted predominantly in forage crops. Water use for alfalfa and other forage crops is also typically three af/yr (Steve King, Palisades Irrigation District, Personal Communication).

Water use during the irrigation season was also calculated for use in a seasonal water balance. The irrigation season was assumed to extend from April through October for a total of seven months. Water use was estimated by summing 7/12 of the annual water system and exempt well usage plus all irrigation use.

5.1 WATER USE IN WRIAS 44 AND 50

Total estimated water usage including irrigation, water systems, and private wells is 62,707 af/yr for the two WRIAs (**Table 5-1**). Water use during the irrigation season is presented in **Table 5-2**. Ninety five percent of the water use in the two WRIAs occurs during the irrigation season. This is because irrigation needs account for 99 percent of the water use, while exempt private wells combined use less than 1 percent of the total.

Eighty-nine percent of the water use occurs within the Columbia River corridor. The remaining 11 percent of the water use occurs over the rest of the two WRIAs (Inland area).

Ninety percent of the water use within the Inland area occurs in the Moses Coulee sub-basin, mostly for irrigation. **Figure 5-2** shows the proportionate annual use by sub-basin. Another three percent of the water use within the Inland area is used in the Douglas Creek sub-basin. Exempt wells use the majority of the water in the Coyote-Strahl and Jordan-Tumwater sub-basins. Groundwater systems use the majority of water in Douglas Creek, Foster Creek, Rock Island/Sand

Canyon/Pine Canyon, Lower McCartney, and Upper McCartney Creek sub-basins.

5.2 PROJECTED WATER DEMAND

Projected water demand for WRIAs 44 and 50 was estimated using four types of data: (1) data on zoning classifications obtained from Douglas and Okanogan Counties, (2) population data obtained from the State of Washington Office of Financial Management (OFM), (3) data on Public Water Systems obtained from the Department of Health, and (4) water use data presented in previous sections of this Assessment.

WRIAs 44 and 50 comprise over 1,818 square miles in Douglas, Grant, and Okanogan Counties. Of that area, 93% (1,698 sq. mi.) is zoned for dryland agriculture (in Douglas County) and approximately 4% (53 sq. mi.) is zoned for irrigated agriculture (also in Douglas County). There are two zoning designations for irrigated agriculture in Douglas County: River-irrigated Agriculture and Commercial Agriculture. River-irrigated agriculture is located along the Columbia River and the water supply for those areas is the Columbia River. The Commercial Agriculture zones obtain water from surface or groundwater supplies, but not from the Columbia River. The northern portion of WRIA 50 is located in Okanogan County, and it is also located on Colville Confederated Tribe land. Currently, this portion of the WRIA has the zoning designation Minimum Requirement District. This classification is intended to maintain broad controls in preserving rural character and protecting natural resources within Okanogan County.

The demand for future water for irrigated agriculture exists in the two WRIAs. This may be satisfied by enhancing existing water supplies. The purpose of the planning effort is to establish a basis for developing future water supplies. Absent a water supply basis, projected irrigated usage can not be estimated at this time.

A trend in Douglas County is conversion of irrigated farmland to residential or commercial/industrial use. That type of conversion is prevalent in the East Wenatchee area and is also occurring in other locations along the Columbia River. The conversions are occurring because of low crop values (the lands are primarily orchards), their more valuable use as residential land and the proximity of the land to Wenatchee (increasing its value as commercial or industrial land). When lands are converted from irrigated farmlands to lawns or landscaping, the total water use often declines as less area is irrigated. The other factor in evaluating whether water use may increase in the future is the present difficulty of obtaining new water rights. Although the Washington State Department of Ecology is currently (February 2002) in the process of issuing new water rights from the Columbia River, the process has been controversial and interrupted by lawsuits. The process may not be completed until new instream flows are set on the Columbia River, which will likely take years because of the large number of agencies and interested parties. Water rights for water sources other than the Columbia River would also likely take years to process.

The water demands for residential, commercial and industrial use are likely to increase in the future because of increased population. Estimates of the increased water demands were made using data on Water Systems obtained from the Department of Health and population data obtained from OFM.

The estimated increase in population in Douglas County for the period from 2001 to 2025 is shown in **Table 5-3**.

The projected population increase in the portion of WRIA 50 in Okanogan County was estimated by multiplying the 2000 population for the Census Tract that best fits that area (Tract 970100 and 970200) by the estimated percent increase in population for the entire County. The results of that calculation are shown in **Table 5-4**.

An estimate of future residential water demand was prepared by multiplying the estimate of per capita water consumption by the projected population. Section 5.0 presented the per connection water demand, based on water use data from the Cities of Waterville and Mansfield. The water demand per connection averaged 460 gallons per day. This per connection estimate was converted to a per capita use by dividing the per connection use by the average number of people in a household in those two cities. The average per capita use is 250 gallons per day (gpd) using that method. That use appears high based upon other water use studies performed by the consultant team but is used as it provides a conservative (high) estimate of future water use. **Table 5-5** shows the estimated future water demands for WRIAs 44 and 50.

Much of the future residential water use will occur in urban areas adjacent to the Columbia River in East Wenatchee, Rock Island and Bridgeport. The water supply for those areas is derived from the Columbia River, either through surface water diversions or from groundwater that is likely in continuity with the Columbia River. An estimate was made of the split of water demands between the areas served by Columbia River water and those inland. The population served by the water systems that obtain water from Columbia River sources in Douglas County was estimated using the Department of Health database on Public Water Systems. That estimated population for current conditions is 25,789. The total is 79% of the total population in Douglas County. To estimate the amount of future water use in the areas adjacent to the Columbia River, we have assumed the same percentage of population applies to water use. The future water demands shown in **Table 5-5** are multiplied by 79% to obtain that estimate. The remainder of the future water use will occur inland. In Okanogan County, we have assumed all of the future demands will occur inland through growth in residential connections. **Table 5-6** summarizes those calculations.

There is slow but continued recreational and permanent residential development in the Rim Rock Meadows development and in Sage Brush Flats.

6.0 RECHARGE ANALYSES

This section includes analyses of recharge to groundwater from precipitation and a recharge/discharge analysis which identifies areas of streams that are gaining or losing water to the underlying aquifer.

6.1 GROUNDWATER RECHARGE

The USGS has made an estimate of recharge to groundwater for WRIAs 44 and 50 as part of the Columbia Basin project (USGS, 1990). The study used the Deep Percolation Model (DPM) which uses geographic distributions of soil type, surficial geology, solar radiation, temperature, stream flow, foliar cover, land cover, and precipitation to estimate recharge. The model was run for 53 sub areas within the model domain (Columbia Basin). The USGS also found that recharge could be estimated in areas of high precipitation using a linear relationship between precipitation and recharge. In areas of low precipitation, the USGS found that estimated recharge is generally small, but is less closely related to precipitation. Therefore areas of low precipitation will likely be affected by the greatest error when using these methods. The USGS study estimated that a maximum error of about 25 percent can be assumed for most zones presented in the report.

The USGS relationship was used to estimate recharge in the two WRIAs. An isohyetal map was used to estimate the average annual precipitation per section. The isohyetal map was produced by the USDA-Natural Resources Conservation Service The USGS relationship was used to convert precipitation to recharge. Total recharge to each sub basin was then estimated by summing the recharge over each sub basin.

Total estimated recharge to the two WRIAs using this relationship is 220,346 af/yr. Recharge to the Inland area alone is approximately 188,337 af/yr. Water recharge by sub-basin on an annual basis is presented in **Table 8-1**, and for the irrigation season (April through October) in **Table 8-2**.

6.2 SURFACE WATER RECHARGE - DISCHARGE ANALYSIS

Recharge/Discharge analysis identifies areas of a stream that are gaining or losing water to underlying groundwater. Two factors control the flow of water between surface water and groundwater: the hydraulic gradient between the two water bodies, and the hydraulic conductivity of the materials between the two water bodies.

Hydraulic conductivity refers to the ability of a geologic material to transmit water. Hydraulic conductivity was assessed using a surficial geology map of the WRIAs (Department of Natural Resources). The geology of WRIAs 44 and 50 in Douglas County is predominated by basalt bedrock overlain by unconsolidated sediments called alluvium. The grain size of the alluvium is dependent on the environment in which it was deposited. Low energy environments such as lakes deposit fine materials like silt and clay. High energy environments such as flood events deposit coarse materials such as gravels and cobbles. The rock types were grouped into four categories in rough order of decreasing hydraulic conductivity: coarse alluvium, undefined alluvium (unknown or mixed grain size), fine alluvium, and bedrock. These groups were then mapped along with the streams of the WRIAs in **Figure 6-1**.

Hydraulic gradient is the difference in elevation between the two water bodies divided by the distance between them. No map exists of hydraulic gradient as it does for geology, however, gradient can be inferred from the conceptual model presented in Section 3.1. Most streams generally gain water as they progress down stream. However, as the streams enter the coarse alluvium surrounding the Columbia River and Moses Coulee, the underlying groundwater is typically at a lower elevation than the surface water. The combination of coarse materials and lower groundwater elevation results in loss of water from the streams. In the case of McCartney Creek and Pine Canyon Creek, the creeks dry completely before reaching the Columbia River.

The eight streams that are the focus of this investigation are: Foster Creek, Rock Island Creek, Douglas Creek/Moses Coulee, Corbaley/Pine Canyon Creek, Coyote Creek, McCartney Creek, Rattlesnake Creek, and Sand Canyon Creek. Geologic analysis and the related hydraulic conductivity are examined on a stream by stream basis. Areas of recharge and discharge may change through out the year based on storm events or droughts. Dam construction, channel alterations such as dredging or straitening, and other human-induced effects may also alter areas of recharge and discharge.

6.2.1 FOSTER CREEK

Foster Creek has three forks, the East, West, and Middle Forks. In general, all three forks are underlain by fine and undefined alluvium. Therefore, Foster Creek likely gains water for the majority of its extent. In the lower reaches of the East Fork and the upper mainstem, the substrate changes to coarse alluvium and water may be lost to the underlying groundwater. However, a dam is located a short distance from the Columbia River and is keyed into bedrock. Surface water will gain significantly as it moves from the alluvium to the bedrock.

6.2.2 ROCK ISLAND CREEK

Rock Island Creek is underlain by bedrock for approximately the first two-thirds of its course form its source. The creek likely gains water along this section. In the last third, the substrate is undefined but is likely coarse alluvium as is most of the surrounding material. Local information suggests that the stream loses water in this area. However, a developed spring exists with in the last mile of the stream which adds significantly to the stream flow.

6.2.3 DOUGLAS CREEK/MOSES COULEE

Douglas Creek winds north-south across most of WRIA 44. The streambed initially consists of fine sediment, but enters a bedrock valley not far along its course. The Creek flows through the valley for approximately half of its total length and then enters Moses Coulee where the substrate changes to coarse alluvium. Within Moses Coulee the creek flow recharges completely to the underlying groundwater and the creek does not discharge to the Columbia River.

6.2.4 MCCARTNEY CREEK

McCartney Creek begins in the northeast portion of WRIA 44 and generally flows towards the southwest. The upper two-thirds of the stream flows through fine sediment (and two large lakes) before entering coarse alluvium where it goes subsurface and potentially rises again as lower McCartney Creek. The creek likely gains water for the majority of this lower section. McCartney Creek flows into Rattlesnake Creek.

6.2.5 RATTLESNAKE CREEK

Rattlesnake Creek trends east-west across WRIA 44. The creek can be roughly divided into three sections based on substrate conditions; the eastern portion consists of coarse alluvium, the middle is bedrock, and the west end is undefined alluvium. The stream likely loses water on the western, downstream reach and loses all of its water to the underlying groundwater before reaching Douglas Creek.

6.2.6 PINE CANYON CREEK

Pine Canyon Creek flows west towards the Columbia River in eastern WRIA 44. The creek substrate changes from fine alluvium to bedrock to coarse alluvium as it flows towards the Columbia River. The creek looses water in the coarse alluvium section and is completely dry before reaching the Columbia River.

6.2.7 COYOTE CREEK

Coyote Creek runs north-south in the northern-most portion of WRIA 50 on the north side of the Columbia River. The streambed substrate consists of bedrock, which changes to coarse, undefined, and then fine alluvium in downstream succession. The Creek likely gains water in all reaches except for the where it is underlain by coarse alluvium. In this section, the stream may lose water to the underlying groundwater.

6.2.8 SAND CANYON CREEK

Sand Canyon Creek flows from east to west in the south western portion of WRIA 44. Water in the creek is predominantly derived from irrigation canals spills. The streambed consists of coarse alluvium for its entire course suggesting a loosing stream. However, local information suggests that the stream generally gains water over its entire length.

7.0 SURFACE WATER ANALYSES

7.1 STREAMFLOW MONITORING

A streamflow monitoring program was initiated to obtain hydrologic data on streams that had not previously been measured in WRIAs 44 and 50. This data was used to estimate the total surface water discharge from the two WRIAs. Though it was intended to be a Level 2 task, the monitoring program was started during Level 1 studies to support surface water runoff analysis for the Watershed Assessment. As a result, five streamflow monitoring stations were installed in June 2001. These stations were Sand Canyon, Rock Island Creek, Douglas Creek, Pine Canyon, and Foster Creek. The Sand Canyon station was removed in late 2001 after determining that streamflow present was derived from irrigation canal spills. In August 2002 three more stations were installed, which are the West Foster, McCarteney and Rattlesnake Spring stations. Monitoring station locations are given on **Figure 1-1** and **Table 7-1**.

The streamflow gaging stations consist of a pressure transducer connected to data loggers, which digitally record the water levels. The water depths recorded by the data loggers were converted to discharge using rating curves at each site. The rating curves were prepared using depth-discharge relationships measured in the field.

The gaging stations have been serviced monthly by Conservation District staff. The work performed during those visits include downloading data from the data logger, rotating batteries, reading the staff gage, and measuring discharge. Discharge is measured by taking velocity readings across a stream cross-section using the Swoffer® velocity metering instrument. The sum of the velocity readings multiplied by corresponding cross-sectional areas is the stream discharge. The discharge measurements are not required for each monthly visit, and thus far six to sixteen discharge measurements have been taken at each site.

In addition to the seven stations listed, an eighth station, consisting of only a staff gage, was installed on private property upstream from the Rock Island station. This station was installed to measure flow from a spring located on the private property. Staff gage measurements were recorded monthly and discharge measurements were taken about every other month, as was done at the other stations.

Rating curves were generated for the seven stations based on the velocity measurements taken in 2001 and 2002; these rating curves allow estimation of stream flow from the stream stage. The rating curves were generated using an approach discussed in the USGS Water-Supply Paper 2175, "Measurement and Computation of Streamflow: Vol. 2 Computation of Discharge". The intent is to establish a channel control in a stable, natural channel. Manning's equation for flow is used with some simplifying assumptions.

$$Q = 1.49/n\ A\ R^{2/3} S^{1/2}$$

At higher stages the energy slope (S) tends to become constant. Furthermore, area (A) is approximately equal to depth (D) times width (W), the hydraulic radius R is appreciably smaller than D, and W is considered a constant. Making the substitutions and expressing $S^{1/2}$ /n as a constant C yields the following equation:

$$Q = C(ght - A)^R$$

where,

Q = Streamflow, cfs

C = Multiplication constant representing relative stream area

ght = Water level height, ft

A = Correction factor for bottom of streambed, ft

R = Curvature factor for cross-sectional shape of streambed

Table 7-2 presents the results of the rating curve analysis for all seven stations. Note that for the stations listed the estimated rating error ranges from 22 to 88%. The rating error indicates the accuracy of the rating curve. For example, a rating error of 22% indicates that estimated flows may be up to ±22% of the actual discharge with 95% confidence. USGS describes rating curves as excellent for a rating error of less than 5%, good (<10%), fair (<15%), and poor (>15%). Following these guidelines, all of the stations result in poor rating curves. However, these streams are very small in comparison to most USGS gaged streams. Small streams are much more difficult to rate than large streams because small irregularities in the channel can have relatively large effects, such as vegetation growth, movement of cobbles, and higher variations in velocity throughout the cross-section. In addition, although apparent rating error is high, the difference in discharge is not great. For example, a rating error of ±22% for a measured discharge of 1 cfs gives an estimated range of 0.8 to 1.2 cfs. The measurement error also usually decreases with additional measurements, and the apparently high rating error also reflects the short period of record and number of measurements taken. **Appendix A** provides graphs of the rating curves and supporting data. Discharge measurements began in June of 2001 and continue to December 2002.

Using the rating curves specified in **Table 7-2**, graphs of stream discharge were generated and are provided in **Figures 7-1 and 7-2**. The same information is provided in tabular form in **Appendix A**.

7.2 ESTIMATES OF STREAMFLOW PRESENT

Estimates of streamflow are presented in the following sections. The methodology used to estimate streamflow was to first separate streamflow records from the WRIAs 44 and 50 streams into baseflow and surface runoff. Estimates for water year (WY) 2002 extended from October 1, 2001 to September 30, 2002. Those baseflow and surface runoff estimates were compared to the same estimates for a nearby stream gage (Crab Creek at Irby) that also has a long-term streamflow record. The long-term average baseflow and surface runoff for the Crab Creek gage was compared to WY 2002 baseflow and surface runoff to review the effect of a dry year (WY 2002) on streamflow. The WY 2002 baseflow and surface runoff estimates for WRIAs 44 and 50 streams were then increased to account for higher long-term average streamflow found in the Crab Creek at Irby streamflow record.

7.3 BASEFLOW AND SURFACE WATER RUNOFF ESTIMATES FOR WRIAS 44 AND 50 STREAMS

Four of the seven streamflow monitoring stations had complete data for WY 2002, which included the stations installed in 2001: Douglas, Foster, Pine Canyon and Rock Island. WY 2002 data from these stations were input into HYSEP. HYSEP is a USGS computer program that is used to separate a streamflow hydrograph into baseflow and surface runoff components. The baseflow component represents groundwater discharge and the surface runoff component represents runoff from saturated overland flow caused by precipitation. HYSEP includes three methods of hydrograph separation that are referred to in the literature as the fixed-interval, sliding-interval, and local minimum methods. The local minimum method was used for the four hydrographs.

Table 7-3 presents a summary of the results of the HYSEP analysis for the Douglas, Foster, Pine Canyon and Rock Island stations. The results are presented in inches, which allows for a comparison of flow values between basins. One inch of runoff has a volume of one inch multiplied by the basin area. **Appendix A** contains the HYSEP output.

7.4 WATER YEAR 2002 PRECIPITATION COMPARISON

Precipitation records show that WY 2002 was a dryer than normal year. Records for WY 2002 at three precipitation monitoring stations within WRIAs 44 and 50 were reviewed. The stations are Waterville, Ephrata AP and Wilbur. Each station has a period of record greater than 50 years. **Table 7-4** presents the comparison of WY 2002 annual precipitation to the long-term average annual precipitation. The average WY 2002 precipitation at those stations was 8.0 inches compared to a long-term average of 10.5 inches. The WY 2002 precipitation ranks in the 18th percentile when compared to the historic record of the three stations. The 18th percentile is approximately equal to a recurrence interval of five years.

7.5 WATER YEAR 2002 STREAMFLOW COMPARED TO HISTORIC RECORDS

A review of historic streamflow data for WRIAs 44 and 50 shows the only gaging station with daily flow data in WRIA 44 was for the Douglas Creek at Alstown gage. The period of record for that gage is from 1949 to 1955 and 1963 to 1968. Because of the paucity of data in WRIAs 44 and 50, data from a nearby stream was used in this analysis. Streamflow information was obtained from Washington State Department of Ecology Water Supply Bulletin No. 60, "Estimated Baseflow Characteristics of Selected Washington Rivers and Streams". The stream gage was selected based on its geographic proximity and its hydrologic regime. It is located in WRIA 43 and is on Crab Creek at Irby, WA (USGS Station 12465000). The gage has a drainage basin of 1,042 square miles. The average annual precipitation in that basin is 9 inches. In comparison, the average annual precipitation for the WRIAs 44 and 50 basins is approximately 10.5 inches.

HYSEP was run on the Crab Creek gage for WY 2002 and for the entire period of record. **Table 7-5** summarizes the output. Total streamflow for WY 2002 was only 44% of the long-term average (about 0.5 inches less than long-term average), indicating a much drier than normal year. In comparison, Table 7-4 indicates the precipitation for WY 2002 was approximately 2.5 inches less than the long-term average.

Table 7-5 also shows that the baseflow comprised 90% of the total streamflow for WY 2002, where it only comprised 60% of the total streamflow for the period of record. The ratio of baseflow for WY 2002 to the long-term average baseflow was 65%; the ratio of surface runoff for WY 2002 to the long-term average surface runoff was only 11%. The lower than normal surface runoff during WY 2002 also reflects the much less than average rainfall that occurred in WY 2002.

7.6 ESTIMATION OF LONG-TERM AVERAGE FLOW

Long-term total streamflow, baseflow and surface runoff were estimated for the four stations that had complete data for WY 2002. Long-term baseflows were estimated for these stations by dividing their WY 2002 baseflow values by the ratio of WY 2002 baseflows to long-term baseflows for the Crab Creek at Irby gage. That ratio is about 1.5. Surface runoff flows were estimated in the same way for these stations: by dividing their WY 2002 surface runoff flow values by the ratio of WY 2002 surface runoff flows to long-term surface runoff flows for the Crab Creek at Irby gage. That ratio is approximately 9. Summing the base flow and the surface runoff flow resulted in total streamflow. This method accounts for the dry year in which data was collected.

Table 7-6 presents estimated long-term average flows for WRIAs 44 and 50 streams. Note that since Douglas Creek had such high base flow, the base flow was not increased for purposes of estimating the long-term average base flow.

The estimated long-term average flows in the WRIAs 44 and 50 streams are much higher than expected when compared to the data collected from the recently installed monitoring stations. However, the monitoring stations have been collecting data during a very dry year. More streamflow monitoring data is needed to better estimate the long-term streamflow from the streams throughout WRIAs 44 and 50. We recommend the monitoring stations be maintained at least through a period of average rainfall to refine the estimates contained in this report.

Table 7-7 presents an estimate of long-term average flow of WRIAs 44 and 50 subbasins. Each of the subbasin flows were estimated by multiplying flow values in inches listed in Table 7-6 by the corresponding subbasin area. The Foster Creek flow values were applied to the Coyote-Strahl, Jordan-Tumwater, Upper Columbia-Swamp Creek, Foster Creek and Upper and Lower McCarteney Creek subbasins. The Douglas Creek flow value was applied to the Douglas Creek subbasin. Rock Island and Pine Canyon stations were combined to estimate the Lake Entiat subbasin flow, since both lie within the Lake Entiat subbasin. Rattlesnake Creek subbasin flow was estimated to be zero by observation. Table 7-7 includes the total streamflow, base flow and surface runoff estimates for each of the nine subbasins.

Table 7-7 should be used with caution because the streamflows change significantly along stream reaches as a function of the underlying geology. For instance, Rattlesnake Spring has measureable flow throughout the year, but further downstream there has not been any observed flow. A more in-depth analysis of each subbasin is recommended prior to using the data for basin-wide instream flow estimates.

8.0 WATER BALANCE

A water balance compares water availability to water use within a given basin. Information available for use in calculating the water balance for WRIAs 44 and 50 included groundwater recharge, surface water base flow, surface water runoff and water use information described in previous sections of this report. Surface water inflow to a basin was estimated as the sum of base flow (surface water derived from groundwater inputs to the stream) and runoff from upstream basins. Unimpacted surface water discharge was estimated as the sum of base flow and runoff for that basin. This flow was considered unimpacted because it is the theoretical flow without water usage subtracted. Unimpacted groundwater discharge was estimated as recharge minus base flow. Base flow must be subtracted since it is groundwater that discharges to surface water and is accounted for in the water balance as surface water. Unimpacted groundwater discharge represents the theoretical quantity of groundwater flowing out of a given sub-basin without usage. One value not available was the groundwater inflow from upgradient basins. This data gap could result in an underestimation of the water available and an overestimation of the percent of water used. For this study, groundwater inflow was estimated as 80 percent of the unimpacted groundwater discharge from upstream basins minus usage. This data gap is addressed in the recommendations section.

Table 8-1 presents a summary of the water balance on an annual basis. Total estimated surface water and groundwater leaving the Inland area is 226,219 af/yr. An estimated 30 percent of the water discharges as surface water and 70 percent discharges as groundwater.

Table 8-2 presents a summary of the water balance for the irrigation season (April-October). Total estimated discharge from the two WRIAs during the irrigation season is 138,791 af/yr, approximately 60% of the annual discharge from the basins. Although water discharging along the eastern border of the WRIAs discharges to Banks Lake and the Sun Lakes, the majority of the water discharges directly to the Columbia River.

8.1 COMPARISON WITH WATER USAGE

Water use as estimated in Section 5.1 was compared to available water in each sub-basin (**Table 8-1**). **Figure 8-1** is a geographic representation of the annual water balance. Available water for most basins was defined as recharge minus base flow because most basins predominantly use groundwater. However, in Moses Coulee and Lower McCartney Creek, base flow, runoff, and surface water inflow were added because much of the water used for irrigation in this sub-basin is derived from surface water. On an annual basis, the largest usage compared to available water is in the Moses Coulee sub-basin (6 percent), followed by Upper Columbia Swamp Creek (3 percent), and Douglas Creek (1 percent). This comparison is very sensitive to the definition of the Columbia River area. If some irrigation that is derived from the Columbia River is attributed to the Inland area, the percent water use in the Inland area could increase greatly.

In **Table 8-1**, water availability was calculated on an annual basis, whereas the dominant usage, irrigation, is seasonal. The actual water available for irrigation is that water available during the irrigation season, which is less than the water available annually. Therefore, a seasonal water balance was also performed by comparing the water used during the irrigation season to the water available during that same time period (**Table 8-2**). Discussion of the seasonal water use calculations is presented in Section 5.0. The percent of available water used during the irrigation season was almost two times the estimates made on an annual basis. The largest usage was again in the Moses Coulee sub-basin (11 percent), followed by Upper Columbia Swamp Creek (5 percent), and Douglas Creek (1 percent).

8.2 WATER RIGHTS COMPARISON

Table 8-3 and **Figures 8-2** and **8-3** show the comparison of water right permits and certificates with annual water availability. Ground water rights are compared with recharge minus base flow plus groundwater inflow from upgradient basins. Surface water rights are compared with base flow plus runoff plus surface water inflow from upgradient basins. The Moses Coulee sub-basin has the largest percent of available groundwater allocated (24 percent and the largest percentage of surface water allocated

(8.0 percent). Upper McCartney (13 percent), Douglas Creek (12 percent, and Lower McCartney (10 percent), all have greater than 10 percent of available groundwater allocated. All other basins have less than 10 percent of groundwater and surface water allocated.

Table 8-4 shows the comparison of allocated water rights and water right claims with water available. Sub-basins that have 50 or more percent of available water allocated are groundwater allocations in Upper McCartney Creek (63 percent) and Moses Coulee (50 percent) and surface water allocations in Upper McCartney Creek (105 percent). Basins having 20 to 50 percent allocated are groundwater allocations in Coyote-Strahl (29 percent), and Douglas Creek (26 percent); and surface water allocations in Rock Island/Sand Canyon/Pine Canyon (34 percent) and Foster Creek (20 percent).

During the irrigation season, a much higher percentage of the available water is allocated to water rights and claims (**Table 8–5, Figures 8-4** and **8-5**). Sub-basins with 100 percent or more of the available water allocated during the irrigation season include groundwater allocations in Upper McCartney Creek (110 percent), and surface water allocations in Upper McCartney Creek (146 percent). Basins with 50 to 100 percent of available water allocated include groundwater allocations in Moses Coulee (88 percent) and Coyote-Strahl (51 percent).

9.0 WATER QUALITY

9.1 WATER QUALITY STANDARDS

Ecology classifies all of the streams included in the WRIAs 44 and 50 study as Class A; Excellent. Water quality standards for Class A waters have been established to provide beneficial uses of the water, which include irrigation, drinking and stock water, habitat for fish and wildlife, and recreation. Water quality standards for Class A waters are summarized in **Table 9-1**.

Waters that do not routinely comply with state water quality standards, even with technology-based pollution control measures, are included on Washington State's 303(d) list. This list is submitted to the EPA for review and approval every two years. The threatened and impaired waterbodies listing is a requirement of Section 303(d) of the Federal Clean Water Act. The final 303(d) list serves as an appendix in the Washington State Water Quality Assessment or Section 305(b) Report. The 305(b) Report was reviewed to determine if any streams in the WRIAs 44 and 50 study are listed as threatened or impaired. No segments of any streams included in the WRIAs 44 and 50 study were on the state's Section 303(d) list published in the most recent 305(b) Report (Ecology 2000).

9.2 SUMMARY OF EXISTING DATA

Limited water quality data were available in WRIAs 44 and 50. Historical information was restricted to Rock Island, Douglas and Coyote Creeks. The Washington State Department of Ecology (Ecology) monitored Rock Island and Douglas Creeks in 1987. Douglas Creek was sampled in 1988 and 1989 by the South Douglas Conservation District (SDCD) and in 1992 and 1993 by the US Geological Survey (USGS). This station has been more routinely monitored by the Bureau of Land Management (BLM) from 1988 to 2001. The Colville Tribe has a long-term record (1994 to present) of water quality data collection in Coyote Creek. Historic water quality sampling stations are shown in **Figures 9.1 and 9.2**

9.2.1 ROCK ISLAND

Ecology's monitoring was restricted to monthly water temperature sampling in 1987. Water temperatures measured in Rock Island Creek in April, May, June, July, and October complied with the state standard for Class A waters (**Table 9.2**).

9.2.2 DOUGLAS CREEK

Water temperatures measured by Ecology in Douglas Creek near the long-term BLM gauging site at RM 1.5 upstream of the confluence with Moses Coulee, over the same time period exceeded the state temperature threshold for Class A waters in May, and July, 1987. The peak temperature measured was 21.1C during the month of May. Ecology also recorded temperature exceedences from May through August for water flowing along the length of Moses Coulee in 1987 (**Table 9.2**). A one-time grab sample of dissolved oxygen (DO) and pH was well within the state's criteria.

The South Douglas Conservation District collected monthly surface water data at 12 locations in the Douglas Creek watershed in 1988 and 1989. Samples included water temperature, discharge, specific conductivity, DO, pH, suspended sediment, turbidity, nutrients and metals data. On August 29, 1992, the USGS measured water temperature, conductivity, DO, pH, and alkalinity in Douglas Creek at the long-term BLM gauging site at RM 1.5 (the lowermost station #12 sampled by SDCD). On September 3, 1993, a more complete water quality characterization was performed by the USGS at the same location. Water quality monitoring conducted by the SDCD and the USGS are summarized in **Table 9-3.**

SDCD data indicate that the low flow tributaries and headwaters of Douglas Creek, where crop production was prevalent, showed high nutrient levels in the late 1980s. Nitrate and phosphate levels were found to be inversely related to stream flow and directly related to suspended sediment levels. According to Isaacson (1989), the uppermost watershed contained high nutrients due to the high percentage of fertilized land and low stream flows that did not dilute the nutrients until lower in the watershed. Shallow groundwater also exhibited high levels of nitrate but low levels of phosphorus. A station in Pegg Canyon (elevation

1,440 ft. MSL) showed the consistent influence of a warm groundwater source (16 to 20C) that contributed 4 to 5 cfs of streamflow year-round to Douglas Creek. Similar to data from shallow groundwater wells, this station had high nitrate levels and low phosphate levels compared to the rest of the watershed. The lowermost SDCD sampling station in Douglas Creek was situated at the long-term USGS and BLM gauge site (elevation 1,375 ft. msl) at RM 1.5. This site is downstream of the influence of both Mohr and Pegg Canyons. Based on a mass balance of stream flows and a signature of conservative water quality constituents, we have estimated the ratio of groundwater and surface water at the BLM site to average approximately 60:40 percent on an annual basis. The groundwater to surface water ratio was in the range of 85:15 percent during the low flow summer months. This example is consistent with stream flow measurements reported in Section 7 that estimate the summer base flow of 11 cfs at this station. Based on these results, additional groundwater with thermal properties is contributing to Douglas Creek flows downstream of the SDCD station #10, below the confluence of Duffy Creek. Although Mohr Canyon waters were not sampled, the surface water in Douglas Creek increased +3C immediately following the Mohr Canyon confluence during a sampling in August 1988. Mohr Canyon drains similar features and has similar orientation as Pegg Canyon. It may be a natural source of additional warm groundwater to Douglas Creek.

The USGS data in Douglas Creek, show that temperature, DO, and pH complied with state standards for Class A waters in 1992 and 1993. The nitrate level (1.10 mg/L) in Douglas Creek was similar to the mean value determined from 71 summer samples from regional streams and rivers with similar geology, physiography, vegetation, and climate (0.93 mg/L) (USEPA 2000). Dissolved and total phosphorous levels in Douglas Creek (0.090 and 0.110 mg/L, respectively) were almost identical to regional averages of 0.087 and 0.109 mg/L from 127 summer samples (USEPA 2000). Washington does not have surface water standards for nitrogen or phosphorus, but the US Environmental Protection Agency (USEPA) has offered recommendations for state criteria that would represent conditions minimally impacted by human activities and protective of aquatic life and recreational uses (USEPA 2000). The Total Kjeldahl Nitrogen (TKN) value in Douglas Creek (<0.20 mg/L) is less than the recommended summer level for the region that would represent minimal human influence (0.28 TKN mg/L).

The BLM data at the long-term gauging site (RM 1.5) at elevation 1,375 ft. msl. indicate that summer water temperatures in Douglas Creek regularly exceed the state water quality threshold of 18C designated to protect beneficial uses in Class A waters (**Table 9-4**). As the SDCD data show, this result is apparently a natural condition due to the influence of groundwater with thermal properties. Nevertheless, the peak temperature measured over this period (22.5ºC) did not exceed levels reported by the USEPA (1986) and Bell (1991) to be lethal to resident salmonid fishes. Dissolved oxygen, pH, and fecal coliform levels consistently complied with state standards. The high DO levels indicated that high water temperatures were not substantially reducing the amount of dissolved gases in Douglas Creek. The pH data depict highly alkaline conditions in Douglas Creek, typical of streams in arid or semi-arid climates. Some of the pH observations approached the high end of the state standard range (< 8.5 +/- 0.5 pH units).

9.2.3 COYOTE CREEK

Water quality results from Coyote Creek indicate that the waters draining the northern portion of WRIA 50 are slightly less alkaline and less mineralized than the interior streams of WRIAs 44 & 50 (**Table 9-5**). Stream flows in Coyote Creek are perennial and have ranged routinely between 0.1 and 35 cfs during spot measurements taken upstream of the county road at the flume station. Most of the stream discharge is associated with the period of spring runoff. Water temperatures generally complied with state standards with an occasional (<4%) warm water excursion. The monthly thermograph depicts a typical steep rise throughout spring with warm summer months and a steep decent in fall (**Figure 9-3**). Winter is typically very cool. The temperature signature suggests surface water runoff dominates stream flows, without substantial groundwater influx.

Dissolved oxygen levels complied with the minimum state standards for Class A waters at all times. They were highly saturated on occasion during the winter months. Monthly DO levels averaged from a low of 9.81 mg/l during summer to a high of 14.34 mg/l during winter. This pattern is consistent with stream temperature regimes in the creek where the capacity to hold oxygen is inversely related to water temperature. Conductivity of the waters ranged from 9 to 165 μmhos/cm indicating generally low to moderate levels of mineralization. Suspended solids and turbidity were typically very low. With respect to nutrient loadings, ammonia levels were low, but dissolved nitrate and phosphate levels were generally high. Nitrate was nearly double, while phosphate was an order of magnitude higher than the regional averages reported by the USEPA (2000). The abundance of phosphorus indicates algal production is routinely more limited by nitrogen levels. Occasional scans for metals indicate less than detectable levels are most prevalent, with some peaks in that exceed USEPA criteria for aquatic resources. The metal data are hard to interpret and appear to include inconsistent errors in reporting of the laboratory measurement units. The tribe should review these data for consistency to confirm analytical comparisons.

9.3 WATER QUALITY DATA COLLECTION

A suite of water quality parameters was monitored in eleven selected study streams under the watershed planning process in WRIAs 44 and 50 to provide a screening level assessment. Water quality parameters included surface water stream temperatures, dissolved oxygen (DO), percent DO saturation, pH, and conductivity.

Water temperature was measured every 30 minutes in each stream using an Onset Optic StowAway continuous temperature recorder. The gauges were installed in the spring and retrieved in the fall to monitor peak summer water temperatures. The temperature recorders were placed inside protective plastic cylinders partially filled with stones to keep them submerged. The units were placed in the deepest part of the channel (thalwag) to ensure they remained submerged during low summer flow periods. The gauges were concealed under a few rocks for protection without restricting stream flow over the instrument. Gauge locations were flagged in the field and documented with field notes. Photographs of each temperature recorder site were also taken for ease of retrieval in the fall.

In situ water quality data were collected with a Hydrolab Surveyor 3 when the temperature recorders were deployed and retrieved. The Surveyor 3 measured temperature, pH, conductivity, DO, and percent DO saturation.

The Foster Creek Conservation District also collected grab samples of water from the mainstem of Foster Creek and from the east and west forks in early July 2001 and continuing in 2002. The water samples were analyzed for selected heavy metals, total phosphorus, and nitrate + nitrite levels. Data from the summers of 2001 and 2002 are included in **Table 9-6** .

9.3.1 CHEMICAL DATA RESULTS

Water quality data collected with the Hydrolab Surveyor 3 during deployment and retrieval of the temperature recorders is summarized in **Table 9-6**.

Temperature. Profiles displaying the maximum, mean, and minimum water temperature in each of the six streams from late-May, 2001 to mid-September, 2002 are presented in **Figures 9-4 through 9-9**. The temperature profile in Foster Creek is not accurate between August 1 and mid-September, 2001. Some time after August 1 the recorder was exposed to air temperature. It was subsequently found on the streambank prior to reinstallation

The temperature monitoring determined that maximum water temperatures in Pine Canyon, Rock Island, Rock Island spring and Rattlesnake Creeks continuously complied with the state standard during 2001 and 2002. Maximum water temperatures in Foster, West Foster, McCartney, and Douglas Creeks exceeded the temperature standard frequently throughout the late spring and summer months, but they remained well below reported lethal temperatures for salmonid fishes. The maximum water temperature recorded during spot measurements in East Fork Foster Creek during 2002 approached lethal temperatures for trout. Maximum water temperatures in Sand Canyon Creek and Blue Grade Draw were very high and exceeded 18ºC almost continuously between mid-June and mid-September, 2001. They exceeded sublethal and lethal water temperatures for salmonid fishes and peaked above 24ºC and 27ºC, respectively.

As discussed in Section 7., the volume of water measured at the upper Douglas Creek site (RM 1.5) at the old rail crossing upstream of the canyon is predominantly groundwater fed. Stream flows are constant year-round and vary little from month to month. Base flow (**Table 7-8**) is estimated to run about 65 percent of the (30-yr) simulated mean annual flow. The 2001 and 2002 flow gauging records indicate base flow ran approximately 87 percent of the annual flow. This estimate is consistent with the mass balance assessment of historic water quality data discussed above in Section 9.2.2 that implies groundwater makes up 85 percent of the total stream flow during the summer months.
The upper Douglas Creek thermograph (Figure 9-5) also shows very little daily or annual fluctuation in water temperature. Both of the continuous flow and temperature graphs provide strong groundwater signals. Surface water runoff from the catchment is typically very low during the summer months suggesting the warm temperatures experienced in Douglas Creek are of natural origin. SDCD data isolated a warm groundwater source in Pegg Canyon (Isaacson 1989). Mohr Canyon may also have a similar groundwater influence on Douglas Creek flows.

Dissolved Oxygen. Dissolved oxygen (DO) concentrations in Rattlesnake, East Foster, Pine Canyon, Rock Island spring, Sand Canyon and Blue Grade Draw complied with the state standard throughout the 2001 and 2002 sampling period. However, DO levels failed to meet the state standard of 8.0 mg/L occasionally in Foster, West Foster, Rock Island and Douglas Creeks in mid-to late summer. Late summer depressions in DO are not unusual because streamflows are lower and water temperatures are higher than earlier in the year. Warm waters do not have as much capacity to hold DO as cooler waters. Therefore, there is less oxygen in the water to satisfy biological oxygen demand, which also increases with higher water temperatures. Nevertheless, the low late-summer DO levels monitored were minor excursions of the standards and they were not believed to be especially adverse for resident salmonid fishes. The DO exceedences occurred when salmonid embryos were not incubating in stream gravels. Salmonid fishes are sensitive to dissolved oxygen levels during incubation and DO should comply with the state standard or be closest to 100 percent saturation during this life-history stage. McCartney Creek showed routine low DO levels during the monitoring period and may reflect a lack of re-aeration due to stagnant water.

There was an unusually high DO level and high percent DO saturation reading in mainstem of Foster Creek during gauge deployment immediately upstream of the irrigation dam in the spring of 2001. There were also very dense growths of green algae on the substrate in Foster Creek at that time. High algal photosynthesis could have caused the supersaturation of DO in Foster Creek, but nutrient samples collected from Foster Creek in July 2001 did not suggest that the waters were especially enriched with phosphorus or nitrogen. An unusually low DO level recorded in the fall of that year may be related to oxygen consumed during algal die-off or decomposition of other organic materials. This pattern did not seem to repeat in 2002 and the algal growth did not appear to be as extensive as the prior year.

Hydrogen Ion Activity (pH). All pH measurements were in the alkaline range but complied with the state standard (between 6.5 and 8.5 +/- 0.5 pH units). One notably high pH reading in Foster Creek occurred in the spring, and corresponded to the very high DO and percent DO saturation levels described previously. High algal photosynthesis could have lowered the carbon dioxide levels in the water, which would have increased the pH in Foster Creek. High pH values on the eastside of the Cascades are common (Hallock et al. 1996; Hallock and Ehinger 1999).

Conductivity. With the exception of Sand Canyon Creek, Blue Grade Draw and Coyote Creek, all streams were moderately to highly conductive. The Foster Creek basin exhibited the highest conductivity (between 700 and 900 μmhos/cm). High conductivities suggest an abundance of dissolved substances and minerals in the water, and it may indicate high soil erosion rates in this basin. Sand Canyon Creek and

Blue Grade Draw serve as irrigation canal spillways. The irrigation water returning to these two channels is diverted from the Wenatchee River. Water quality data for the Wenatchee River provided by Ecology shows that the Wenatchee River is not as conductive as the other four streams.

Metals and Nutrients. Concentrations of total cadmium and total chromium in Foster Creek were below detection, and were less than chronically or acutely toxic levels when adjusted for ambient water hardness (**Table 9-6**). Only molybdenum registered values above the minimum level of detection and they were very low, less than 12.6 ug/L (ppb).

Total phosphorus and nitrate/nitrite concentrations in the Foster Creek basin generally were low to moderate; less than 0.130 and 0.540 mg/L, respectively (**Table 9-6**). These values are in the range of, or less than, the mean summer value for the region (USEPA 2000). One high phosphorus value of 0.380, nearly 4 times the regional average was recorded in the mainstem of Foster Creek during August of 2002.

Total Kjeldahl Nitrogen (TKN) is a measure of organic levels of nitrogen. The measured levels were typically low in the Foster Creek basin, with the exception of some very high organic nutrient loading during late spring and early summer in all of the monitored stream reaches. Both the West and East Forks supported the highest organic nitrogen levels; 1.5 to 1.6 mg/L, respectively. Although the levels remained relatively high, some dilution was apparent in the mainstem of Foster Creek as organic nitrogen concentrations were cut in half to 0.8 mg/L.

9.3.2 BIOLOGICAL MONITORING RESULTS

Biological monitoring consisted of random spot measurements of fecal coliform bacteria conducted by the FCCD at three locations in the Foster Creek basin and benthic macroinvertebrate surveys in eleven stream reaches.

Fecal Coliform Bacteria. Bacterial testing results were highly variable during the summer months of 2002 in the Foster Creek basin. Counts of fecal coliform organisms ranged from few to 'Too Numerous to Count' (TNTC). Half of the 12 samples collected in the mainstem and in both East Fork and the West Fork exceeded the state water quality criterion of 100 organisms/100 ml. The months of July and August appeared to exhibit the greatest bacterial concentrations.

Macroinvertebrates. Benthic macroinvertebrates are the visible component of invertebrate organisms living on or within the stream bottom. This community of organisms offers many advantages to monitoring stream health since they are diverse, abundant, easy to collect, sedentary, and have relatively short life spans of several months to a few years (Platts et al. 1983). These characteristics allow macroinvertebrate communities to reflect local conditions and the recent past, making them good indicators of proximate, acute impacts. They also represent an important food source for resident and anadromous (migratory) fishes.

The goal of the macroinvertebrate monitoring was to characterize the spring macroinvertebrate fauna on a screening-level basis in eleven streams in WRIAs 44 and 50. Specific qualities of the macroinvertebrate community that were characterized are described in Appendix B and summarized in **Table 9-7**.

Methods: Sampling methods generally followed the Department of Ecology's protocols for benthic macroinvertebrates (Plotnikoff 1994). Three samples were collected from each of the eleven streams using a D-frame kick-net sampler fitted with 500-micron (µm) Nitex mesh. All three samples were collected in riffles or shallow runs possessing coarse gravel to small cobble substrates. All samples were collected from water depths between 0.0 and 1.0 ft deep, and mean water column velocities between 1.0 and 3.0 ft per second, except where noted. The depth, mean column velocity, and substrate composition of each sampling location were recorded in a field notebook. Specific field, laboratory, and data analysis protocols are described in Appendix B.

Results: Late spring monitoring of macroinvertebrate communities in the eleven streams suggests a wide range of habitat conditions exists among the streams (**Table 9-7**). The data indicate that Sand Canyon Creek and Blue Grade Draw contain a low density and diversity of macroinvertebrates and that the fauna is comprised entirely of short-lived taxa. The majority of the taxa exhibit burrowing habits that allow them to survive in temporary habitats when streamflows cease. The macroinvertebrate community in the nine naturally flowing streams was more abundant and diverse and more evenly represented by various macroinvertebrate groups. Furthermore, the benthic fauna comprised short- and long-lived taxa with varying habits. The macroinvertebrate community in each stream consisted primarily of collector-gatherers, which reflected the seasonal availability of food resources and an abundance of fine particulate organic matter (FPOM).

The macroinvertebrate data imply relatively good water quality and habitat conditions occur in perennial reaches of Douglas, upper Pine Canyon, Rock Island, Coyote and McCartney Creeks compared to the other streams surveyed. Using the metrics described in Ecology (1996), habitat seems to be "slightly impaired" in Foster and West Foster Creek and "impaired" compared to natural conditions in Sand Canyon, Blue Grade Draw, East Foster and Rattlesnake Creeks. Lower Moses Coulee and lower Pine Canyon creek are not conducive to benthic invertebrate production due to the lack of surface water stream flow throughout the year. Detailed monitoring results are included in Appendix B1 and B2 for data collected during late spring 2001 and 2002, respectively.

9.3.3 PHYSICAL MONITORING RESULTS

Preliminary physical channel survey work was conducted to describe sediment characteristics in eight study streams. A US Forest Service stream reach inventory/channel stability evaluation and Wolman pebble counts were performed to assess channel bank conditions and to provide a cursory examination of sediment transport concerns.

Stream Reach Inventory, Channel Stability Evaluation (SRI/CSE). Each of the study reaches was evaluated using the US Forest Service-developed SRI/CSE methodology (Pfankuch 1978). This method is generally used to assess the capacity of the channel to adjust and recover from potential changes in flow and/or increases in sediment production (Pfankuch 1978).

The field methodology for the SRI/CSE is to rate fifteen variables related to the upper and lower stream banks and the channel bottom, based on a visual assessment (Appendix C). The specific ratings are summed to generate an overall numeric reach stability score. Each reach is then classified into one of four categories, as follows: poor (115+), fair (77-114), good (39-76), or excellent (less than 39).

Results from the SRI/CSE evaluation in the WRIAs 44 and 50 study streams indicate the survey reaches generally have fair to good stability ratings. The average channel stability rating for eight survey reaches was 79, ranging from a low of 48 to a high of 102 (**Table 9-8**).

There were few visual indicators of channel instability for the eight survey reaches. Excessive bank erosion or failures were present where riparian vegetation was lacking, but such features did not dominate any specific reach. Stream channels generally consisted of a single thread with only localized areas of channel braiding. Channel migration is present in alluvial fan areas where tributary streams enter the Columbia River floodplain. Although stability ratings for all the survey reaches were either good or fair, channels with these ratings are often sensitive to sediment loading (Pfankuch 1975). For channels of this nature, degradation of spawning and rearing habitats and water quality indices can occur with only a small increase in sediment loading.

Wolman Pebble Count. The composition of streambed substrate is a crucial factor in stream channel behavior and can provide important information about channel response to changes in a watershed (Montgomery and Buffington 1993). Although visual characterization of substrate composition was completed as part of the baseline fish habitat assessment (Section 10.2), fluvial geomorphologists prefer the use of a pebble count to classify substrate composition in gravel-bedded streams. Pebble counting consists of measuring the intermediate axis of stones chosen from the riverbed along a transect (Wolman 1954). Generally, riffles channel habitat is chosen since the

information collected is indicative of the bed material transported through the channel rather than material deposited at some location in a stream. Cumulative frequency distributions and grain size statistics are determined from the pebble samples. The median diameter (D_{50}) and the diameter of the 84th percentile (D_{84}) are values used by many scientists to characterize bedload transport in gravel-bedded streams.
The pebble count was performed by randomly selecting 100 particles from the streambed of a representative habitat riffle and measuring the intermediate axis of each pebble. Individual particles were chosen at random while traversing the stream channel from bankfull stage to bankfull stage along an imaginary zigzag line, as described in the USFS Region 6 Stream Inventory Handbook (1998). One sample was collected within six surveyed stream reaches.

The D_{50} has been shown to be useful for modeling sediment transport and it provides some insight into the biological capability of the stream. Channels that are dominated by fine sediments tend to have lower productivity of salmonid fishes and aquatic macroinvertebrates than stream reaches with somewhat larger sediment sizes. Pebble count survey data were plotted to develop particle size distribution curves (Appendix D) and the results are presented in **Table 9-9**.

In general, substrate particle size is determined by the parent geology of a stream basin. This finding is evident in the relatively small D_{50} found in Sand Canyon and Coyote Creeks. The Sand Canyon Basin is composed of an old massive slump containing abundant fines, silts and aeolian sands. Hardly any bedrock is exposed in the drainage; therefore little cobble and gravel is present (Section 10.1.1; Channel Characterization). Similarly, the lower stream reach of Coyote Creek traverses an old slump downstream of the strong bedrock contact at the falls. The geology upstream of the bedrock contact is quite different as reflected in the pebble count data.

Stream bed substrates in three study reaches exhibited D_{50} size classes of medium gravel and contained relatively low percentages of fines less than 6 mm in diameter (**Table 9-9**). Pine Canyon, Rock Island and upper Coyote creeks contain an interesting mix of small (D_{35}) and large (D_{95}) particle sizes, which is indicative of stream channels with limited transport capacity. The parent material in Rock Island Creek and upper Coyote Creek drainages is largely basalt, such that resistant coarse particles and very fine material are prevalent. Pine Canyon Creek has a relative unique geology for WRIAs 44 and 50; consisting of biotite gneiss. It supports high levels of mica and likely weathers to fine materials.

Although the frequency of fines (< 6 mm, 0.24 in.) and D_{50} in Foster Creek are generally consistent with the other samples, the D_{95} (64.0mm, 2.5 in.) is the lowest size class in the survey. This result implies the transport capacity is sufficient to clear out the very fine material, but that sediment aggradation is overwhelming the channel's ability to transport small and medium sized gravels. Consequently, large bed elements capable of providing habitat structure and diversity in Foster Creek are not generally exposed. The parent material is glacial drift over basalt, so some level of large bed material would be expected. The prevalence of very small gravel suggests a limited transport capacity for this creek.

10.0 HABITAT

10.1 HISTORIC HABITAT IDENTIFICATION

10.1.1 STREAM CHANNEL CHARACTERIZATION

Channel morphology is a useful tool for evaluating the potential aquatic habitat quality of streams and rivers because it: (1) dictates habitat conditions used by the various life-history stages of salmonid species (Beechie and Sibley 1997), (2) directly influences the productive capacity of each habitat type (Vannote et al. 1980; Naiman et al. 1992; Paustian et al.1992), and (3) varies in terms of sensitivity and response to changes in inputs of water, wood, and sediment from natural or man-made disturbances or from restoration activities (Paustian et al. 1992; Montgomery and Buffington 1993; Rosgen 1997).

The channel morphology of seven streams in WRIAs 44 and 50 was evaluated using topographic maps and aerial photographs. Channel segments with consistent geomorphic characteristics and response potential were delineated based on landform, stream gradient, channel confinement, and channel planform. The evaluation indicates that the underlying geologic parent materials, which vary between basins, strongly controlled channel morphology. The following sections present a brief discussion of channel segment types, geomorphic processes, and current conditions for each drainage.

Foster Creek. The Foster Creek basin is located in the southwestern half of WRIA 50. It originates on the Waterville Plateau and drains northward, emptying into the Columbia River downstream of Chief Joseph Dam. The Foster Creek basin consists of three major tributaries: East Fork Foster Creek, Middle Fork Foster Creek, and West Fork Foster Creek.

The Foster Creek basin is located in the area covered by the Okanogan lobe of the most recent glaciation. The underlying bedrock consists of tertiary flow basalts. In the Foster Creek basin, the basalt flows are overlain by a relatively thick layer of glacial till and outwash, and are only exposed at high elevations (Gulick and Korosec 1990). Valleys in the Foster Creek basin are incised into the glacial deposits, intersecting bedrock at some sites. The glacial materials are susceptible to erosion; therefore, valley bottoms tend to be wide with very low gradients. In many cases, multiple terrace systems are apparent, particularly in upland areas. The photographic evidence suggests many channels are currently incising through old, wide valley bottoms. Gully erosion was observed on small tributaries throughout the basin. Occasionally, small inner gorge failures occur where large, laterally mobile channels flow adjacent to steep valley walls.

Foster Creek and its tributaries were subdivided into nine channel segments (**Figure 10-1**) as follows:

- Columbia River Floodplain (River Mile [RM] 0.00 to 0.98)
- Cascade (RM 0.98 to 1.03)
- Mainstem Valley (RM 1.03 to 1.70)
- East Fork Foster Creek – unconfined alluvial (RM 1.70 to 5.85)
- E.F. Foster Creek – glacial coulee (RM 5.85 to 22.55)
- W.F. Foster Creek – high gradient confined (RM 0.00 to 7.15)
- W.F. Foster Creek – incised upland (RM 7.15 to 10.40)
- M.F. Foster Creek – high gradient confined (RM 0.00 to 6.20)
- M.F. Foster Creek – incised upland (RM 6.20 to 7.40)

The river mile conventions used herein follow the Pacific Northwest River Basins Commission river mile index for the Columbia River Basin (PNWRBC 1968). Foster Creek begins at RM 0.0 at its confluence with the Columbia River (Columbia River Mile 544.5) and river mile index continues sequentially upstream as East Foster Creek to its headwaters. Other tributaries in this basin begin again at RM 0.0 were they meet the mainstem.

The lowermost mile of Foster Creek flows across the floodplain formed by the Columbia River. Foster Creek downcut through sediments deposited by the Columbia River in this area rather than forming a pronounced alluvial fan landform. The fact that Foster Creek enters on the outside of a meander bend formed by the Columbia suggests the river may have rapidly mobilized sediment delivered from Foster Creek, precluding the formation of a well-developed alluvial fan landform. The gradient through this section is low (1 to 2 %).

A very short, steep cascade section has formed where Foster Creek cuts across the valley wall that was formed by the more rapid downcutting of the Columbia River. This section contains a 35-foot high dam built in the early 1900s. Bartu and Andonaegui (2001) cite evidence that the dam was built where a bedrock falls was thought to historically preclude further upstream anadromous fish passage. .

Upstream from the falls the stream gradient remains low for another 0.70 miles, to the confluence with East Fork Foster Creek. This mainstem valley segment appears to be aggrading. The entire reservoir area is currently filled with coarse sediment. Large amounts of deposited sediment were observed in 1994 aerial photos.

The East Fork of Foster Creek is the largest tributary in the Foster Creek system, joining the mainstem at approximately RM 1.70. This tributary flows through a relatively wide, steep-sided valley that was carved into glacial drift and glacial lacustrine deposits. The channel has a moderate gradient (1 to 2 %) and extensive in-channel sediment deposits occur in this shallow channel segment.

The reach break is gradual between channel segments four and five in East Fork Foster Creek (**Figure 10-1**). The channel gradient slowly decreases to less than one percent, and in-channel sediment deposits noted in the photographic record become scarce. East Fork Foster Creek appears to be an underfit stream (small with respect to the size of the valley) from RM 1.70 to beyond the upstream extent of mapped stream channels. The valley is wide and deep, and it extends east to Banks Lake. It is most likely an overflow channel carved by the Spokane floods.

The Middle and West Forks are distinctly different from East Fork Foster Creek. These channels are steep and confined at their downstream ends, with gradients of approximately three percent. Channel segments six and eight clearly represent valleys formed by incision of the present channel network through unconsolidated glacial material. These segments represent transport reaches, meaning that sediment delivered from upstream areas is rapidly routed downstream.

Approximately seven miles upstream of the confluence with East Fork Foster Creek, West Fork Foster Creek emerges from the canyon and flows in a low gradient, incised channel across the Waterville plateau. Multiple terrace systems representing former valley bottoms and channel locations were noted in this area. West Fork Foster Creek and many of its tributaries appear to be actively incising in this area.

In contrast, Middle Fork Foster Creek appears to be an underfit stream occupying a valley formed by glacial activity rather than fluvial erosion. The channel in the upper Middle Fork of Foster Creek is less incised and it is unconnected with the distinctive overflow channel network formed by the Spokane floods. The channel has a very low gradient (<1%) and is unconfined through Buckingham Flats. Buckingham Flats is a depositional reach for even very fine sediments, and it currently contains extensive wetlands. The Middle Fork discharges to the West Fork of Foster Creek at RM 3.0.

Pine Canyon Creek. The Pine Canyon basin is located in the northwestern portion of WRIA 44, draining west and slightly south to the Columbia River. The geology of the Pine Canyon basin is distinctly different from that of the majority of the study area. Bedrock consists of biotite gneiss of the Swakane terrane (Tabor et al, 1987). This rock is older than the Columbia River flow basalts, and is common across the Columbia in the lower Chelan River drainage. The Columbia basalt flows appear to have displaced the river to the north and west. It subsequently downcut across the old bedrock, isolating a small exposed section of the gneiss in the vicinity of Pine Creek Canyon.

Pine Canyon Creek was subdivided into three channel segments (**Figure 10-2**) as follows:

- Alluvial Fan
- Canyon

- High-gradient Confined

Pine Canyon Creek has developed a small but distinct alluvial fan on the Columbia River floodplain. The channel gradient in this segment is 4.8 percent. The fan appears to be composed of coarse, subangular sediments deposited as a result of very large floods. Surface stream flows across the fan are rare and water travels beneath the surface, except during major storm events. No surface water was flowing on the alluvial fan channel segment downstream of SR 2 Highway bridge (RM 1.23) during all surveys conducted in 2001 and 2002.

The middle section of Pine Canyon Creek occupies a steep-sided bedrock canyon. The valley floor is approximately 500 feet wide, and is almost entirely filled with coarse sediment similar to that found on the alluvial fan. Flow across this sediment deposit is subsurface for much of the year. The gradient through this segment is greater than five percent. In fluvially dominated systems, such steep channels are generally able to transport sediment delivered from upstream reaches. The presence of extensive coarse sediment deposits suggests that the system is dominated by mass wasting processes or that a wave of fluvially deposited sediment may currently be working its way through the system.

At an elevation of around 1,600 feet, Pine Canyon splits into two main tributaries: Pine Canyon and Corbally Canyon Creeks. Both of these channels occupy steep-sided V-shaped valleys with gradients in excess of 5 percent. These channels appear to be functioning as transport reaches and no large accumulations of sediment were noted.

Sand Canyon Creek. Sand Canyon Creek is located in the extreme western edge of WRIA 44, flowing through the town of East Wenatchee before joining the Columbia River just downstream of the Wenatchee River confluence. Sand Canyon Creek drains a very small area of land composed almost entirely of a large quaternary landslide complex. The landslide material is composed of fine-grained basaltic diamictite (Tabor et al. 1982).

Sand Canyon Creek was subdivided into two channel segments (**Figure 10-3**) as follows:

- Fan (RM 0.0 – 0.8)
- V-shaped Valley (RM 0.8 – Headwaters)

The fan segment extends from the confluence with the Columbia River to the point where the channel enters a V-shaped valley near RM 0.8. The “fan” segment is not a true alluvial fan landform built by deposition of material from Sand Canyon Creek itself, but rather the distal portion of the ancient landslide deposit. The channel is weakly incised into this material. The gradient of the fan segment is high (4.8%) and it is believed that sediment delivered from upstream reaches is systematically routed downstream.

Upstream of RM 0.8 the channel and its tributaries are incising into the ancient landslide deposits, forming a narrow, V-shaped valley. This segment is a transport reach, delivering sediment eroded from the bed and banks to the fan segment.

Rock Island Creek. Rock Island Creek, located in the southwestern portion of WRIA 44, flows south from its headwaters near Badger Mountain for approximately 20 miles before joining the Columbia River just upstream of Rock Island Dam. The Rock Island Creek drainage basin is underlain by layers of flow basalts above and below a thin layer of Ellensburg formation sedimentary rocks (Tabor et al. 1982). Loess deposits are present at high elevations. A number of very large Quaternary landslides (younger than that described for Sand Canyon Creek) are mapped near the mouth of Rock Island Creek.

The mainstem of Rock Island Creek and its major tributary, Beaver Creek, have both carved steep-sided canyons through this resistant parent material. Bedrock outcrops are common along the canyon walls.

Rock Island Creek has been subdivided into four channel segments (**Figure 10-4**) as follows:

- Alluvial Fan (RM 0.0 – 0.3)
- Lower Canyon (RM 0.3 – 7.8)

- Cascade (RM 7.8 – 8.0)
- Upper Canyon (RM 8.0 – Headwaters)

A very small alluvial fan exists near the confluence with the Columbia River, but within 1,400 feet Rock Island Creek enters a steep-walled canyon. The longitudinal gradient across the fan is approximately 5 percent.

Rock Island Creek occupies a canyon for most of its length. The lower Canyon segment (RM 0.3 to 7.8) has a gradient of approximately 3.2 percent. Aerial photographs indicate that the 200 to 500 foot wide canyon floor is currently filled with extensive sediment deposits and that the channel pattern throughout the reach is braided. Historic accounts describe lower Rock Island Creek as "a serene pastoral setting, with intermittent groves of cottonwood, aspen and serviceberry" (WDOE 2000). However, between 1948 and 1957 a series of large floods dramatically altered the channel conditions, reducing the river bed to huge boulders, river rock, sand, and silt. As a result of these floods, the formerly year-round flow now goes subsurface in the lower canyon most years (WDOE 2000). Evidence of the landslides and debris flows that occurred during these floods was still evident on the valley walls in aerial photographs dating from 1978.

Near RM 8.0 the creek flows across a very resistant layer of bedrock known as the Hammond sill, and the gradient increases dramatically to over seven percent. Although no direct observations of this area were made, it is likely that the channel bedforms are predominantly cascades formed by boulders and bedrock in this segment.

Upstream of RM 8 in the upper canyon segment, the gradient decreases to approximately 3.3 percent. The valley floor is narrow, averaging 100 to 200 feet in width. The upper canyon segment does not appear to have been as dramatically impacted by the historic flood events as the lower canyon segment. The riparian vegetation is still intact (Section 10.1.2), and a single thread channel is visible in places. The canyon continues to the headwaters of Rock Island Creek. The Creek splits into very small tributaries on the relatively flat surface of Badger Mountain.

The historic descriptions of Rock Island Creek indicate that there were numerous beaver dams in the upper reaches. Beaver dams may play an important role in sediment retention, flood attenuation, and summer low flow maintenance in stream systems like those found in WRIAs 44 and 50. No information on the presence or absence of beaver was located for other drainages in WRIA 44, but it is likely that they occupied and may have significantly influenced channel morphology in other streams in the area as well. Beaver activity influencing the channel and habitat features was noted along the mainstem channel of Foster Creek in WRIA 50 during 2001 surveys.

Moses Coulee/Douglas Creek. Moses Coulee and the Douglas Creek basin make up the majority of the drainage area of WRIA 44. Douglas Creek originates on the Waterville plateau and flows south for approximately 20 miles before entering the northeast- to southwest-trending Moses Coulee, ultimately discharging into the Columbia River. Moses Coulee is a former overflow channel of the Columbia River that was subsequently eroded by a series of enormous floods originating from the periodic breaching of an ice-dammed lake that had formed east of Spokane. These floods excavated the channels and left alluvial deposits several hundred feet thick.

The Moses Coulee/Douglas Creek basin was subdivided into five channel segments (**Figure 10-5)**, as follows:

- Moses Coulee Alluvial Fan (RM 0.00 to 0.70)
- Moses Coulee (RM 0.70 to 16.70)
- Douglas Creek High Gradient Fan (RM 0.00 to 0.70)
- Douglas Creek Canyon (RM 0.70 to 13.60)
- Douglas Creek Plateau (RM 13.6 to Headwaters)

A small alluvial fan has formed where Moses Coulee enters the Columbia River. The fan is composed of primarily (1) fine material (sand and gravel) transported through the very low gradient Moses Coulee segment and (2) coarser materials recruited locally from the stream banks.

Upstream of the alluvial fan, the creek flows through the wide flat Moses Coulee. The valley is overfit, meaning that it was formed by flows much greater than those of the present day stream. This drainage basin continues to be subject to large seasonal flow events and channel disturbances. The gradient through this segment is very low (<0.3%). In 1927 the US Army Corps of Engineers dredged and diked this channel such that it is confined in its present location in the valley bottom.

At RM 16.7, Douglas Creek joins Rattlesnake Creek and forming the mainstem of Moses Coulee. Douglas Creek has a large alluvial fan extending from the mouth of the canyon out into the valley bottom. At least three active or historic distributary channels are visible on the fan surface. The active stream channel is dynamic as a result of the bedload deposition. For example, the county road on the fan currently fords the creek across sheet flow that has left its primary channel. Because it is an aggradational feature the alluvial fan's gradient is high relative to the downstream reaches. The fan is composed of material routed through the canyon segment at high flows, and consists of a mixture of sediments ranging from sand and gravel up to boulder sized materials.

Upstream of the high gradient fan, Douglas Creek flows through a bedrock canyon. The canyon is very narrow with nearly vertical sideslopes. The initial highly confined canyon is steep but the headwater gradient is fairly mild, averaging 1.2 percent along the entire length of the upper watershed. The headwater is fed by a number of large tributaries originating on Badger Mountain to the west and shorter tributaries originating on the plateau to the north. There was no evidence of extensive flood deposits like those observed in Rock Island or Pine Canyon Creeks. Valley sideslopes and tributary channels appeared to be stable, exhibiting little evidence of mass wasting on the photographic record.

10.1.2 RIPARIAN HABITAT

Riparian habitats in WRIAs 44 and 50 were characterized from 1978 and 1994 aerial photographs. The black and white 1978 photographic surveys were flown for the Washington Department of Transportation at a scale of one inch equals one mile (1:63,360). The 1994 photo set consisted of 2-meter resolution black and white digital orthophotos obtained from Douglas County. Riparian conditions were mapped at a scale of approximately one inch equals 500 feet (1:6,000) from the 1994 orthophotos using ArcView software.

Riparian habitat conditions along the mainstem channels and large tributaries were evaluated following the general protocols outlined in the Washington State Board Manual for conducting Watershed Analysis (WDNR 1997). Riparian vegetation was classified as conifer trees, deciduous trees, mixed conifer and deciduous, and non-forested. If present, the tree size was categorized as large, medium, or small, and the canopy cover was rated sparse (<50% canopy cover) or dense (>50% canopy cover). Since it is often difficult from the aerial photographs to distinguish between vegetation communities dominated by dense shrubs and small trees, communities described as deciduous young dense or shrub were lumped together as one category. Qualitative notes were recorded describing riparian vegetation patterns and conditions on small tributaries.

Due to the large scale, riparian conditions in the 1978 photographs were difficult to evaluate. Areas with tree cover were identified and delineated on 1:24,000 scale topographic maps, but no information on tree type, density, or non-forest conditions was recorded. Riparian vegetation types identified within WRIAs 44 and 50 on the 1994 aerial photos are summarized in **Table 10-1**.

The following sections describe riparian conditions within each of the study stream basins.

Foster Creek. Riparian vegetation communities were evaluated along the three main forks of Foster Creek. The majority of the stream length evaluated was bordered by non-forested vegetation types.

On West Fork Foster Creek, short, narrow stands of hardwood trees were noted in two locations, 1) approximately 1.5 miles upstream from the confluence with East Fork, and 2) upstream of the confluence with Middle Fork. The locations and extent of the tree stands did not change substantially compared to the

1978 photo set. The channel appeared to be incised and eroding banks were visible in many locations. Conditions in small tributary streams were generally similar, with few small patches of trees or shrubs present. Gully development was noted on several small tributaries. The existing riparian vegetation types and distribution suggests that both shade and large woody debris (LWD) recruitment are limited in West Fork Foster Creek, and that the lack of streamside vegetation may contribute to bank instability.

Forest riparian community types were more common in the Middle Fork Foster Creek drainage. Occasional trees bordered most of the channel length. Shrub communities were extensive in places, particularly through Buckingham Flats. Conditions in small tributary streams were generally similar to those noted in the West Fork Foster Creek drainage, with a few small patches of trees or shrubs present.

East Fork Foster Creek occupies a wider valley than either West Fork Foster Creek or Middle Fork Foster Creek, and much of the area has been managed at one time or another for agriculture. Riparian zones bordering more than 60 percent of the mapped channels had a component of trees, but the vegetation zones were classified as sparse and narrow, with canopy cover of less than 50 percent. As a result, riparian communities consisting of large-sized trees capable of contributing to various channel or habitat-forming functions were rare. Dense shrub or small tree communities were also rare. These vegetation types may have always been rare in the basin. Such conditions indicate that both shade and LWD recruitment are lacking. East Fork Foster Creek appears to be a low gradient pool-riffle channel, and additional channel structure would increase both the hydraulic complexity and sediment storage capability of the channel.

Small tributary drainage channels in the East Fork Foster Creek basin were steep and non-forested. Small channel landslides or gullies were noted on the aerial photographs in several areas.

Pine Canyon Creek. Pine Canyon Creek was unique among the channels evaluated because it was the only area where conifer trees were a component of riparian communities. The most downstream portions of the creek are non-forested, but occasional conifers occur along the canyon walls. A channel segment with scattered hardwood trees was mapped approximately 1.5 miles upstream of the confluence with the Columbia River.

Pine Canyon Creek is formed by two major tributaries: Pine Canyon Creek and McGinnis Canyon Creek. Stands of conifer trees become common on north- and east-facing valley walls upstream of the confluence of these two tributaries. McGinnis Creek is bordered for much of its length by a dense stand of medium to large hardwoods, mixed with conifers at high elevations. Pine Canyon Creek is also bordered by medium sized hardwood trees, although the riparian zone is often narrow and conifers are scarce. Conditions observed in the 1978 photos indicate there has been little change in the location or extent of riparian tree communities in the last quarter of a century.

The prevalence of medium to large-sized trees, including some conifers, in riparian areas along upper Pine Canyon Creek and its tributaries indicates that there is a potential supply of large woody debris. There is a scarcity of trees or shrubs along the lower reaches of the channel since water does not flow there during the growing season.

Blue Grade Draw. The lower reaches of Blue Grade Draw flow adjacent to SR 2 and through the rural-residential community of East Wenatchee. The lowermost reach was mapped with medium-sized, dense hardwoods and shrubs. During the fish habitat assessment, the area was described as having luxurious riparian growth lying along the stream channel where summer flows are maintained by irrigation return flow (RM 0.0 to 0.27).

The existing riparian community appears to provide adequate shade to the wetted portion of Blue Grade Draw. Even in the lower portion of Blue Grade draw, where riparian vegetation is dense, the trees and shrubs adjacent to the stream are limited in their LWD recruitment potential.

Sand Canyon Creek. Similar to Blue Grade Draw, the lower reaches of Sand Canyon Creek flow through the rural-residential community of East Wenatchee. The lower 1.5 miles of the stream are bordered by a mixture of residential properties, orchards, and a county park. Riparian vegetation throughout this section consists of an almost continuous but narrow band of small to medium deciduous trees, mixed with areas of shrubs. Upstream of the developed areas and agricultural lands where the channel transitions into the V-shaped valley segment, the channel is bordered by a sparse stand of low shrubs for approximately half a mile. The steep hillsides bordering the headwater areas and tributaries support sagebrush, and streamside trees or shrubs are largely absent.

Trees within the riparian zone bordering the lower channel segment provide shade and represent a potential source of LWD. However, the density of residential and agricultural land uses on both sides of the stream likely limit the longevity of in-channel LWD and shade. Trees that could enter the stream and potentially form log jams or redirect flow or shade orchard trees are probably removed to protect humans and their property.

Rock Island Creek. The Keane family, early settlers in the area, established a ranch in the Rock Island Creek valley in 1887. Interviews with the family's descendents indicate that the Keane family cut wood in the cottonwood groves along lower Rock Island Creek (Bartu and Andonaegui 2001). Construction of roads and railroads facilitated access to the area, and cattle and horses were grazed in the valley bottom. Beaver were also described as harvesting wood in the cottonwood groves.

Conditions in the stream channel and riparian zone reportedly changed dramatically as a result of a series of large floods in the 1940s and 1950s (Section 10.1). Riparian vegetation is currently scarce along the lowermost 2.6 miles of Rock Island Creek, consisting of scattered low shrubs and occasional small trees. Differences were noted between the 1978 and 1994 aerial photos. The lowermost portion of Rock Island Creek, downstream from the highway bridge, is currently bordered by a stand of small trees and shrubs. The stream discharges into a backwater marsh of the Columbia River that supports dense shrubs and willows. The largest trees and the widest zone of riparian vegetation occur along the creek in the vicinity of the man-made springs near RM 0.52.

Upstream of RM 0.52, the creek is seasonal and riparian vegetation is sparse. Above the confluence with Beaver Creek there is a small grove of medium-sized deciduous trees along the river, but the banks generally remain un-forested until approximately RM 3.8. Upstream of this point to the headwaters (RM 8.0) the stream is bordered by medium to large deciduous trees in a continuous band, varying from sparse to dense. The narrow riparian zone likely provides LWD and shade to the channel throughout this reach.

Similar conditions were noted on Beaver Creek. At high elevations conifers become more common and they sometimes occur adjacent to small tributary channels. The largest tributary channels typically support a narrow band of deciduous trees along the channels.

Moses Coulee/Douglas Creek. Poor photographic quality precluded evaluation of the lower section of Moses Coulee, but riparian vegetation was mapped upstream of the Highway 28 bridge (RM 1.4). Extensive agricultural development has occurred in Moses Coulee. The US Army Corps of Engineers dredged and artificially constrained the channel for much of its length for flood control. The county has similarly constrained the channel at various locations for road development. No riparian tree or shrub communities were noted until about RM 16, where the channel traverses the alluvial fan formed at the mouth of Douglas Creek. Scattered large trees were noted along all of the distributary channels crossing the fan, but canopy cover was generally less than 20 percent.

Trees were scarce within the bedrock canyon of Douglas Creek (RM 0.7 to 13.6) as well, occurring only occasionally as isolated individual trees along the canyon walls. At approximately RM 13.6, where the stream enters the upper end of the canyon, the valley widens somewhat and the channel is bordered by shrubs and small trees. Riparian vegetation is generally low and sparse until the creek reaches the town of Douglas (RM 16.6). A narrow band of medium to large deciduous trees extends for about a half mile along the channel at this point. Upstream of the town of Douglas the headwaters and tributary channels flow through farm fields.

Tributaries entering the canyon from Badger Mountain to the west frequently support stands of mixed deciduous and conifer trees adjacent to the channels. Trees are more common and are predominantly coniferous at high elevations. Riparian zones along high elevation tributary channels may serve as a source of LWD to downstream reaches, but overall LWD recruitment in the Douglas Creek basin is low.

10.2 BASELINE HABITAT DATA COLLECTION

During the summer of 2001 and 2002, physical, hydrological, and biological conditions of seven streams with potential access to the Columbia River were assessed. The habitat conditions considered included: (1) anadromous fish access assessment, (2) physical channel assessment, and (3) habitat assessment including such features as pool and wood frequencies, spawning gravel abundance, riparian vegetation conditions, and stream flows with respect to the potential aquatic biological productivity of each stream. The initial findings are documented in Appendix E and are discussed below for each stream.

10.2.1 ANADROMOUS FISH ACCESS

In general, the topography and landforms within the WRIAs limit the access of anadromous fish to tributary streams entering the Columbia River. The high plateau of the Columbia Basin breaks off sharply near the canyon walls of the Columbia River creating (1) very steep, cascading stream reaches through inter-gorge canyons and (2) extensive alluvial fans at the mouths of these streams as channel gradients flatten near the river. Low summer stream flows often go subsurface across these areas, restricting fish access and rearing capabilities. Steep gradients in the canyon areas upstream of the alluvial fan are generally not conducive to anadromous fish production.

Blockages to the upstream and downstream migration of anadromous fish species were found in all of the streams surveyed to date. Man-made structures, including a dam in Foster Creek [River Mile (RM) 1.03] and irrigation control structures and road culverts in Blue Grade Draw (RM 0.27) and Sand Canyon Creek (RM 0.35), limit the potential for further upstream migration. Migratory blockages in the form of dry stream channels were noted in all other streams surveyed, including Pine Canyon Creek downstream of the SR 2 Highway Bridge (RM 0.0 to 1.23), Blue Grade Draw and Sand Canyon Creek during periods when irrigation water is terminated, Rock Island Creek upstream of the excavated springs near RM 0.55, and Moses Coulee downstream of the confluence with Douglas Creek (RM 0.0 to 16.7). Many of the flow blockages are natural conditions that existed historically in the WRIAs, prior to land use development.

The presence of anadromous salmonid fish in Foster Creek and Rock Island Creek was confirmed during 2001. Two other streams had limited observations of anadromous salmonid use: Sand Canyon and Moses Coulee (WDF 1987, Bartu and Andonaegui 2001). Anadromous fish use was not observed in these streams in 2001. Two other streams, Pine Canyon Creek and Blue Grade Draw, have occasional access to the Columbia River and the potential for at least temporary anadromous fish use. However, neither of these streams supported anadromous species during 2001. Coyote Creek is upstream of Chief Joseph Dam, a barrier to migratory fishes. However, future fish passage facilities at this structure are desirable and the Planning Unit agreed to assess Coyote Creek during the summer of 2002 for it's future potential to support anadromous fish production. An assessment of the waterbodies in relation to the potential for migratory fish access is shown in **Table 10-2**.

Foster Creek. Foster Creek is accessible year-round to anadromous salmon and steelhead trout migrating through the Columbia River up to Chief Joseph Hydroelectric Facility, the US Army Corps of Engineers' mainstem dam. This facility is the lowest on the Columbia River without provision for anadromous fish passage. Since Foster Creek enters the Columbia River from the south shore at Columbia RM 544.5, immediately downstream of Chief Joseph Dam, it is currently the most upstream tributary in the Columbia River Basin with anadromous fish production.

Summer-run steelhead trout were observed spawning in the creek between RM 0.28 and 0.98 in late May 2001. Young-of-the-year juvenile trout rearing in the anadromous fish section were noted throughout the summer low flow season. These fish have upstream access to a steep, cascading stream section complete with numerous bedrock falls that is just short of an approximately 35 ft. high dam built in a tight bedrock constriction near RM 1.03. The Bridgeport Irrigation District reportedly constructed the dam during the early part of the 20th Century as an irrigation water supply. The dam and subsequent irrigation were abandoned when bedload materials consisting of coarse and fine sediments filled the reservoir, eliminating the facility's capacity to store and deliver water. It is reported that the dam was built in the vicinity of a bedrock falls that historically limited anadromous fish passage (Bartu and Andonaegui 2001).

Low stream flows, measured at the dam site the summers of 2001 and 2002, have been continuous but low, ranging between approximately 0.6 and 4.0 cfs. Base flows occurring during the month of August were in the vicinity of 1.0 cfs. A series of springs along the middle and west forks and along the west side of the mainstem of Foster Creek support continuous flow.

Pine Canyon Creek. Pine Canyon Creek is not accessible to anadromous fish because stream flows are subterranean across the alluvial fan and downstream of the SR 2 Bridge to the creek's confluence with the Columbia River (RM 0.00 to RM 1.23).

Upstream of the SR 2 Highway Bridge, small volumes of ground or hyporehic water are forced to the surface and flow was present throughout the summers of 2001 and 2002. This expression of surface water may be in relation to zones of shallow bedrock in the vicinity (Section 3.0, Hydrogeology and Groundwater Flow). Riparian vegetation is abundant where surface water is present and generally lacking along the dry stream reach. This observation generally supports the assumption that near surface water, upstream of SR 2, is available during most of the growing season. Stream flow monitoring at RM 1.62 indicates summer surface waters flow between 0.2 and 0.4 cfs. The lowest flows were measured during the month of September (Section 7.0, Streamflow Monitoring).

Blue Grade Draw. Blue Grade Draw is the first drainage system immediately south of the SR 2 crossing of the Columbia River on the Douglas County side. It lies within the city of East Wenatchee. It is supported entirely by irrigation return flow originally withdrawn from the Wenatchee River. Surface water generally flows during the March to October irrigation season. The stream channel is reportedly dry during the balance of the year. Luxurious riparian growth covers the stream banks, indicating the presence of water during the growing season. The channel appears to be accessible to anadromous fish species during this period, but actual use has not been documented.

Streamflow from the upstream drainage basin is directed to the north of SR 2. Thus, when irrigation water is terminated, the channel dries completely. During the irrigation season, surface flow begins at the irrigation structure at RM 0.27. From this point the streamflows underneath SR 2 and daylights on the south side at RM 0.23. The stream channel downstream of this point is poorly defined, running over roots and masses of grass and through thickets of riparian willows as it winds its way onto a short, alluvial fan with multiple, shallow distributary channels at the confluence with the Columbia River. The alluvial fan may pose a low flow passage impediment to the upstream migration of returning adult fish.

Sand Canyon Creek. Sand Canyon Creek enters the Columbia River on its eastern shore approximately two miles downstream of SR 2. It flows within the city limits of East Wenatchee, Washington. Surface water in the creek is supported by irrigation return flow during the summer months. Water from the irrigation ditch flows is siphoned into the stream channel at approximately RM 0.54 and flows downstream to the SR 28 crossing (RM 0.35), where it is recollected and distributed to local orchards by means of a head gate and irrigation manifold. The balance of unused water continues downstream in the channel to the Columbia River. Without irrigation water, it is assumed that this channel would be dry during the early spring and summer season and would remain dry until periods of intense rainfall.

Anadromous fish have access to the section of Sand Canyon Creek downstream from the SR 28 road crossing and irrigation manifold. No fish were observed in Sand Canyon Creek during our May 2001 field survey, but Washington Department of Fish and Wildlife (WDFW) personnel have observed juvenile anadromous fish species in the lower section during the 1990s. These fish were assumed to be seasonal migrants from the Columbia River rather than fish produced in Sand Canyon (Bartu and Andonaegui 2001).

A streamflow gauge was installed immediately downstream of the manifold structure and recorded the summer flow in this portion of the channel. For the period of record (May-September 2001), flows ranged between approximately 0.5 and 3.0 cfs, with the lowest flows occurring during the month of August (Section 7.0, Streamflow Monitoring).

Rock Island Creek. Rock Island Creek enters the Columbia River on its eastern shore immediately upstream of Rock Island dam (Columbia RM 453.5). Streamflow in Rock Island Creek is currently supported by a perennial flowing spring located at approximately RM 0.52. This spring was excavated in the 1950s for stock watering purposes following channel-altering floods that buried the previous stream channel. The channel upstream of the spring generally remains dry from early spring to late fall of each year (Keane 2001). As such, anadromous fish are assumed to have access all year to Rock Island Creek from the confluence with the Columbia River upstream to RM 0.52.

During habitat surveys conducted in late-May, 2001 young-of-the-year salmonid fry in the range of 50 to 60 mm in size were observed in the creek near its confluence with the Columbia River (RM 0.04). Based on size and parr mark patterns, these fish were assumed to be either chinook or coho salmon. Whether the observed fish were the offspring of parents spawning in Rock Island Creek or emigrated from the Columbia River could not be determined. Spawning gravel was observed sporadically throughout the survey reach upstream to approximately RM 0.44. WDFW observed spawned-out adult coho salmon carcasses in the lower reach of Rock Island Creek during the 1980s (Bartu and Andonaegui 2001).

As reported at the gauge located at RM 0.17, low summer streamflows in Rock Island Creek during 2001 and 2002 generally ranged between 0.1 and 1.0 cfs. The spring appears to be a near-surface expression of groundwater, likely as a result of shallow bedrock in the vicinity (Section 3.0, Hydrogeology and Groundwater Flow). During low flow periods, it was estimated that surface flow from the spring contributes approximately one half to three fourths of the flow observed in Rock Island Creek. Additional groundwater seepage may make up the balance of streamflow at RM 0.17. The spring offers a base flow of around 1 cfs during July and August, but the contribution declines in September and October. The decrease in surface water contribution in fall indicates a typical time lag in groundwater response to percolation input rates. This information supports the hypothesis that the surface and groundwater bodies in lower Rock Island Creek are closely connected.

Moses Coulee. Anadromous fish did not have access to Moses Coulee and any upstream tributaries during 2001 and 2002 as a result of dry stream channels. Channel observations indicate it may have been more than three years ago that there was stream flow in the channel. There are no other physical barriers to upstream fish migration in the channel. WDF and WDG documented anadromous fish use in Moses Coulee during the 1970s and 1980s in the lowermost 1.8 RM of the Coulee.

Further assessment will be needed to determine the relationship between upstream water sources and their expression as potential surface water stream flows in Moses Coulee.

10.2.2 FISH HABITAT ASSESSMENT

Stream channels were typed in reaches accessible to anadromous fish according to gradients, channel and valley confinements to describe channel processes and other physical characteristics available for fish habitat formation. The channel typing system included a combination of Montgomery and Buffington (1993) and Paustian (1992) approaches for describing the value of certain channels for fish use. The channel morphologies described below are at a small scale and are considered subsets of the overriding channel segments defined in each basin in Section 10.1.1, Stream Channel Characterization.

Pools and in-channel loading of large woody debris (LWD) are important channel features for aquatic habitats and they were assessed during the 2001 surveys. The frequency that pools occur along a stream channel is a fundamental aspect of channel morphology (Montgomery et al. 1995). Pools may be formed by either hydraulic interaction of sediment and water movement, or they may be forced by local flow obstructions such as boulders, bedrock outcrops or LWD. As example, the typical pool spacing in self-formed pool-riffle channels, one of the most productive channel types, is on the order of 5 to 7 channel widths between pools. The frequency of pools can be increased in this channel type to approximately 2 to 4 channel widths between pools under conditions of high LWD loading. Pool spacing is a primary channel attribute that is very sensitive to LWD loading in Pool-Riffle channel types.

Foster Creek. The reach of Foster Creek, downstream of the concrete dam at RM 1.03, consists primarily of four channel morphologies:

- Alluvial Fan (RM 0.00 to 0.05)
- Step-Pool (RM 0.02 to 0.36)
- Pool-Riffle (RM 0.36 to 0.98)
- Cascade-Falls (RM 0.98 to 1.03)

The alluvial fan consists of coarse and fine sediments deposited at the point where the channel gradient decreases as the stream enters the Columbia River. Stream gradients are generally less than one percent and riffle habitat accounts for about 42 percent of the reach length (**Table 10-3**). A small amount (60 ft.^{2}, 5.6 m^2) of spawning gravel was recorded in this section. The usefulness of this reach as a spawning area is somewhat reduced by the backwater elevations of Wells Pool and tailrace of Chief Joseph Dam which inundate most of the fan during high pool elevations.

The step-pool channel reach (RM 0.02 to 0.36) has a moderately steep channel gradient (2.5 to 5 percent) with a series of pools separated by short cascading sections. Small amounts of spawning gravel were observed in riffles associated with pool tailouts. A total of 91ft.^{2} (8.5 m^2) of spawning habitat was observed in this section during the May 2001 survey. Although this channel type is generally considered a sediment transport reach, a possible steelhead redd was seen at RM 0.28. Step-pool channels are a productive habitat type for rearing juvenile steelhead trout. The lowermost portion of this stream section has been channelized and straightened, likely in relation to construction of Chief Joseph Dam and the road bridges crossing the lower channel.

The pool-riffle reach (RM 0.36 to 0.98) in Foster Creek is low gradient (<0.5 to 1.5 %). Approximately 431 ft.^{2} (40 m^2) of spawning gravel was mapped and the majority of steelhead spawning activity was observed in this reach. However, high levels of fines were noted in the streambed. The embeddedness of dominant substrate particles with fine sediments was rated at 50 percent or higher in approximately 20 percent of the sampled habitat units. These levels of sedimentation have been associated with biologically meaningful reductions in survival to emergence of incubating salmonid embryos and alevins, the amount and diversity of invertebrate prey species for fry, over-wintering habitat, and refuge space from predators. Since steelhead trout are spring spawners, the embryos incubate in the gravel on the descending limb of the hydrograph. This life-history strategy reduces the likelihood of adverse siltation effects on embryo development. Nevertheless, current levels of siltation could adversely influence rearing habitat in Foster Creek.

The cascade-falls reach (RM 0.98-1.03) in Foster Creek occurs in a bedrock constriction that drops roughly 50 ft. in elevation over a distance of 300 feet (17 % gradient). It is unlikely this reach contains considerable anadromous spawning or rearing habitat. None of the salmonid fishes noted during May 2001 were observed in this section.

Reaches upstream of the bedrock constriction and the diversion dam include the West, Middle and East Forks of Foster Creek. They channel networks are associated with resident salmonid production areas only.

Pine Canyon Creek. The survey reach upstream of the SR 2 crossing (RM 1.23) consists of a single channel morphology:

- Pool-Riffle (RM 1.23 to 1.62).

The pool-riffle reach is low to moderate gradient (1.0 to 2.5 percent). The habitat sequence is alternating pools and riffles with only one cobble step classified as cascade habitat. Pool habitat frequency was generally low; less than ten percent of the reach by length is composed of pool habitat (**Table 10-3**). Although a spawning area survey for this stream reach was not conducted, stream bottom substrates were characterized as having a high composition of small to large gravel with occasional cobble accumulations. Channel substrates were generally clean (low percent fines) with silt or sand substrate dominant in only a few habitat units. Although pool habitat was limited, the abundance of available, clean gravel should be conducive to successful spawning and rearing and the production of key prey items for salmonid fishes.

The lowermost 1,000 feet of the surveyed reach contains very little riparian vegetation, with sage and grasses as the dominant species. Small bank failures and actively eroding banks were common. The upper 1,000 feet of the reach contained dense riparian vegetation of deciduous trees and shrubs providing excellent streamside shade, overhanging cover, and stream bank stability.

Blue Grade Draw. The survey reach downstream of the SR 2 crossing (RM 0.23) primarily consists of two channel morphologies:

- Alluvial Fan (RM 0.00 to 0.01)
- Step/Pool-Riffle (RM 0.01 to 0.23)

The alluvial fan consists of coarse (small gravel) and fine sediments where the channel gradient decreases as the stream enters the Columbia River. Stream gradient is generally less than 1.0 percent and riffle habitat accounts for the entire reach length. A single patch (12 ft.^{2}, 1.1 m^2) of spawning gravel was mapped within this section. Streamflow was dispersed across the fan resulting in low average water depth (0.3 ft.). The lowermost portion of this section may be susceptible to inundation during high pool backwater elevations behind Rock Island Dam.

The step-pool reach is moderate gradient (2 to 4 percent). The habitat sequence is alternating pools with cobble/boulder steps separating the pool units. A total of 48 ft.^{2} (4.46 m^2) of spawning gravel, distributed in small patches throughout the reach, was mapped. Stream bottom substrates were characterized as having a high composition of silt and sand accumulations, probably due to the high consistency of fine-grained material eroding from the stream banks. Spawning and rearing habitat, and food production may be compromised as a result of fine sediment levels noted in Blue Grade Canyon Creek.

Sand Canyon Creek. The stream reach downstream of the SR 28 crossing of Sand Canyon Creek consists of primarily two channel morphologies:

- Alluvial Fan (RM 0.00 to 0.05)
- Pool-Riffle Channel (RM 0.05 to 0.35)

The alluvial fan consists of coarse (small gravel) and fine sediments deposited where the channel gradient decreases as the stream enters the Columbia River. Stream gradient is generally less than 1.0 percent and riffle habitat accounts for all of the reach length (**Table 10-3**). A single patch (12 ft.^{2}, 1.1 m^2) of spawning gravel was mapped within this section.

The pool-riffle reach is low gradient (0.5 to 1.5 percent). The habitat sequence is alternating pools and riffles with occasional cobble steps that were classified as cascade habitat. A total of 200 ft.^{2} (18.6 m^2) of spawning gravel, distributed in small patches throughout the reach, were recorded. Stream bottom substrates were characterized as having a high composition of silt and sand accumulations. This observation corroborates the pebble count data presented in Section 9.3.3, likely as a result of the high composition of fine-grained material eroding from stream banks. Spawning, rearing, and food production may be compromised as a result of fine sediment levels noted in Sand Canyon Creek.

Rock Island Creek. It is assumed anadromous fish species have year-round access from the confluence of Rock Island Creek and the Columbia River upstream to the man-made spring located along the north side of Rock Island Creek at RM 0.52.

The reach downstream of the springs at RM 0.52 can be delineated into 2 channel morphologies consisting of:

- Alluvial Fan (RM 0.00 to 0.08)
- Pool-Riffle Channel (RM 0.08 to 0.52)

The alluvial fan reach consists of coarse and fine sediment deposition where the channel gradient decreases near the railroad and highway bridges and as the stream enters the Columbia River. Stream gradients are generally less than 1.0 percent and riffle habitat accounts for about 90 percent of the reach length (**Table 10-3**). A small amount (74 $ft.^2$, 6.9 m^2) of spawning gravel in this section was mapped.

The pool-riffle reach is low gradient (0.5 to 1.5 percent). An estimated total of 154 $ft.^2$ (14.3 m^2) of gravel, distributed intermittently throughout the reach, was available for spawning. High levels of fine sediment accumulations were not observed in the channel, reflecting the spring-fed character of the stream. Spawning and rearing habitat and food production should not be compromised as a result of fine sediment levels noted in Rock Island Creek.

Moses Coulee. Habitat and flow data descriptions for Moses Coulee are not available since the channel was dry during the 2001 site visit. The channel appeared to have been dry for several years. Other than dry stream channels, there are no other known physical barriers to upstream fish migration. Historic information was relied upon for developing recommendations.

Moses Coulee was formed by the Columbia River in relatively recent Pleistocene time (10,000 years ago) when the river, diverted by a large ice lobe near the present day Grand Coulee Dam, cut through the thick basalt formations of the Columbia River Plateau (Bartu and Andonaegui 2001). The basalt layers vary in thickness from 6,000 to 10,000 feet and date primarily from the Miocene epoch (30 million years ago). Erosion and formation of Moses Coulee and other river meltwater channels in the region (including the Grand Coulee) were augmented by enormous floods from the glacial Lake Missoula.

The resulting valley bottom is flat today. The entire width between the canyon walls is filled with several hundred feet of glacial and river deposits. The alluvial materials along the valley bottom are large and porous. Although the upstream drainage basin is large, the mainstem Coulee is typically dry for many years at a time. It is likely that surface water summer streamflows were historically low, with most of the stream flowing in subsurface layers. The condition of the channel surface downstream of the Highway 28 bridge indicates it currently transports only peak stormwater flows. The recurrence interval of such peak flows occurs sporadically and may be a time scale of once every 5 or 10 years. Small base flow conveyance channels etched between the very wide storm terraces are limited, suggesting water, if present, flows within the porous alluvial materials at all times except during the largest floods.

Perennial flowing stream reaches in Moses Coulee have not been apparent for a number of years. Limited evidence indicates year-round flow occurred at times during the 1970s and 1980s and that the stream supported anadromous fish species (WDF 1987). Washington Department of Fisheries (WDF) and Washington Department of Game (WDG) survey data from the 1970s and 1980s documented anadromous fish use in the lowermost 1.8 river miles in Moses Coulee. Two size classes of juvenile chinook salmon (young-of-the-year fry and yearling pre-smolts) and yearling pre-smolt steelhead trout were observed (WDF 1987). Although no redds (spawning nests) or suitable spawning habitat were observed during the surveys, the Departments assumed anadromous fish species were migrating into Moses Coulee from the Columbia River system for seasonal rearing purposes to take advantage of winter habitat provided by boulders, small pools, woody debris and vegetation growing on the banks and in the creek bed. During winter surveys the fish were collected in deep, low velocity pools with boulder or woody debris cover. WDF captured no anadromous fish during the low flow summer period in Moses Coulee. They assumed the lack of fish presence was due to low streamflows and high water temperatures (20 to 22ºC). WDF concluded juvenile salmonid fish rearing is limited to the fall, winter and early spring periods. They recommended instream flows be established in Moses Coulee to protect seasonal rearing (WDF 1987).

Habitat conditions appear to have changed considerably since the 1980s because the 2001 survey indicated an abundance of spawning gravel was present in the same channel section and an absence of large woody debris and shoreline vegetation. It is possible that a flood of considerable magnitude rearranged the channel conditions near the mouth of Moses Coulee since the WDF surveys. Floods of 1989, 1991, 1993 and 1995 were of sufficient volume to be channel-forming events. It is clear that the dynamic nature of storm events can alter surface water hydrology and habitat conditions such that fish production is intermittent and irregular. Changes in channel and hydrogeological conditions may have influenced the present ability of the channel to transport surface water flows.

It is also possible that base stream flows in the Coulee are related to the volume of groundwater entering Douglas Creek in the vicinity of Pegg and Mohr Canyons. Douglas Creek supports perennial stream flow in the canyon reach, but looses surface water flow across its alluvial fan. During the period WDF, WDG and Ecology observed year-round stream flow in Moses Coulee, Douglas Creek was flowing at an uncharacteristically sustained high level near 20 cfs. The flow gauging record in Douglas Creek indicates such high expression of surface water flow did not routinely occur in the proceeding or subsequent decades. From a limited amount of information, it appears streamflow in Douglas Creek needs to approach or exceed 20 cfs before surface water flows through the coulee. Since stream flow in Douglas Creek at the gauge site is strongly correlated with groundwater discharge, fluctuations in groundwater volumes, on a time scale of decades, ultimately influence continuity of surface water flows downstream. Additional study is needed to determine the dynamics of the groundwater source and if groundwater recharge can be enhanced.

11.0 HABITAT CONCERNS

During the summer of 2001 and 2002, the physical, hydrological, and chemical habitat conditions were assessed in seven streams in WRIAs 44 and 50. The objective was to assess the historic and current potential of each stream to support aquatic species of concern on an initial or screening-level basis. As a consequence, this effort is cursory in nature and, given the overall paucity of historical information, this assessment should be regarded as preliminary. More detailed work is recommended under Level 2 studies to verify or confirm the preliminary findings reported herein.

The initial Level 1 findings are summarized as Section 9.0 Water Quality and Section 10.0 Habitat. The detailed results are appended. This section, Habitat Concerns, addresses specific stream reaches with habitat conditions that may have a potential to adversely influence the production of salmonid fishes.

11.1 WATERBODIES WITH WATER QUALITY CONCERNS

Based on a review of available data records and site-specific field collection during the summers of 2001 and 2002, it is apparent that surface water conditions in local streams support fairly good water quality conditions. However, some adverse conditions occur in various streams as itemized below:

11.1.1 WATER CHEMISTRY

Temperature. Water temperatures vary considerably in the study area streams due to weather patterns, stream discharge, channel shape, shading, and the influence of groundwater or hyporehic flows. Rock Island, Pine Canyon and Rattlesnake Creeks support summer water temperatures that are relatively cool as a result of springs, groundwater flux and/or hyporehic streamflows. Streams in the Foster Creek basin are also supported by springs, but the open channel, shallow cross section and lack of a substantial riparian zone contribute to warming of the surface waters. The continuous temperature gauges located in mainstem of Foster Creek at the dam site during 2001 and 2002 recorded relatively warm surface water temperatures, peaking around 22°C. Spot measurements in the West and East forks show that water temperatures peaked in early June, 2002 at 18.6°C and 22.5°C, respectively. Temperatures above 18°C, due to human activities, exceed the state water quality criterion. When natural conditions exceed 18°C, no temperature increases are allowed that raise the water temperature by more than 0.3°C. Water temperatures above 19°C are generally thought to influence growth and development of salmonid fishes. Temperatures above 23°C can be lethal, depending upon the fish species and the acclimation period (USEPA 1986; Bell 1991). The recorded temperatures in the Foster Creek basin did not exceed lethal levels and, given the brief duration above 19°C during the monitoring period, they did not likely pose a severe detriment to rearing salmonid fishes.

Douglas Creek above the canyon at RM 1.5 supports naturally warm stream temperatures (<22.5°C), but due to the brief duration, they were not necessarily detrimental to cold-water fish production. However, peak summer stream temperatures in Douglas Creek have a history of exceeding 18°C as a result of large volumes of warm groundwater influx from Pegg Canyon and possibly Mohr Canyon. In such situations the state water quality standards restrict human caused temperature increases to less than 0.3°C.

Conversely, Blue Grade Draw and perhaps Sand Canyon Creek were too warm for summer rearing fish production. Peak temperatures were recorded near 27°C in Blue Grade Draw and 24°C in Sand Canyon. The peak daily temperatures exceeded lethal and sub-lethal conditions for salmonid fishes for extended periods of time in Blue Grade Draw and Sand Canyon Creek, respectively, throughout the months of July and August.

Dissolved Oxygen. Dissolved oxygen (DO) levels in portions of the fish-bearing streams were generally very good. These results indicate that appropriate levels of re-aeration are occurring in the flowing streams. The only areas of concern were in McCartney and Foster Creeks. In McCartney Creek there is evidence of a lack of re-aeration due to stagnant water. DO concentrations ranged between 5.8 and 9.0 mg/L (63 to 82% saturation) with 83 percent of the recordings reported below the state criterion of 8.0 mg/L.

Abundant plant growth and large fluctuations in DO concentrations were observed in Foster Creek during the late summer months of 2001. Measured DO concentrations ranged from 6.6 to 11.8 mg/L (representing 67 % to 130 % saturation). A combination of both over- and under-saturated DO levels may indicate oxygen dynamics related to plant respiration and photosynthesis. During periods of high light, an abundance of plants can produce concentrations of oxygen that over-saturate the normal holding capacity for DO in water. However, during evening hours or periods of low light without photosynthesis, decomposition of organic matter and plant respiration create an oxygen deficit. As such, diurnal swings in DO concentrations can be dramatic in situations of over-stimulated plant growth. Dissolved inorganic nutrient levels do not necessarily suggest a high level of enrichment, but the data may be misleading because the information represent levels of nutrients in the water column after plant uptake. The lack of a riparian zone and the open and relatively shallow channels expose much of the mainstem reach to sunlight. DO levels should be monitored more closely in Foster Creek and the cause of low DO levels determined.

One late-summer DO measurement in Rock Island, West Fork Foster and Douglas Creek fell slightly below the minimum state water quality criterion of 8.00 mg/L. However, the magnitude and duration of these exceedences do not pose a direct threat to salmonid fish production. There is not a history of dissolved oxygen excursions in any of these three creeks.

Hydrogen Ion Activity (pH). All acidity and alkalinity levels monitored during the 2001 and 2002 monitoring period were within the Class A water quality criterion between 6.5 and 8.5 units +/- 0.5 pH units. The waters were generally alkaline in nature, typical of arid and semi-arid conditions. Douglas Creek and streams in the Foster Creek Basin were the most alkaline, while Rattlesnake, McCartney, Rock Island and Pine Canyon Creeks were neutral to slightly alkaline. Blue Grade Draw and Sand Canyon Creek water reflected irrigation withdrawals from the Wenatchee River system. They were neutral in pH and supported relatively soft waters compared to other local streams.

Conductivity. Conductivity is a relative measure of mineralization in streams. Interior streams of the Columbia River Basin under arid and semi-arid conditions often consist of relatively ‘hard’ waters as a result of evaporation and soil erosion. Groundwater inputs also generally increase stream mineralization. Data collected during the 2001 and 2002 monitoring period indicate hard waters persist in local streams, with Rock Island Creek exceeding 200; Douglas Creek exceeding 300; Rattlesnake and McCartney Creeks exceeding 500; Pine Canyon exceeding 600, and streams in the Foster Creek basin falling between 700 and 900 µmhos/cm. The high measurements from Foster Creek waters likely express a combination of groundwater input, high levels of soil erosion, and high evaporation (open canopy). Conductivity levels of the irrigation return flows in Blue Grade Draw (30-50 µmhos/cm) and Sand Canyon Creek (60-150 µmhos/cm) are uncharacteristically low in mineralization compared to local streams, reflecting the soft water source of the Wenatchee River. Coyote Creek, draining lands north of the Columbia River, is similarly low in mineralization, with levels typically falling between 100 and 200 µmhos/cm.

Organic Compounds. Historic water quality data from USGS gauging stations are available on a few streams in WRIAs 44 and 50. The station on Douglas Creek includes detailed information of the analytical results of scans for organic compounds. Most organic compounds were reported below detectable or at very low levels, but there was a historical signal of elevated levels of hexa-chlorobenzine and P, P’ DDE at the station on Douglas Creek (USGS 1992). Since sampling occurred in the early 1990s, these results may not represent current conditions. The reported organic levels may reflect a legacy of agricultural pesticide and/or herbicide use in the basin.

Nutrients. Measurements of nitrogen- and phosphorous-related compounds representing nutrient sources are generally lacking from flowing streams in the watersheds. Dissolved components of these nutrients are available for plant uptake and, if excessive, can stimulate luxurious growths of attached periphyton and algae. Limited spot measurements are available in Foster and Douglas Creeks. Nutrient concentrations were not measured during this study effort.

Data from samples in Douglas Creek in 1988/1989 and 1993 indicate that the low flow tributaries and headwaters of Douglas Creek, where crop production was prevalent, showed high nutrient levels in the late 1980s. The highest nitrate concentrations were in excess of 3.50 mg/L and peak phosphate levels exceeded 0.300 mg/L, frequently. Nitrate and phosphate levels were found to be in an inverse relationship with stream flow and a direct relationship with sediment levels. According to Isaacson (1989) the uppermost watershed contained high nutrients due to the high percentage of fertilized land and low stream flows that did not dilute the nutrients until lower in the watershed. Although diluted somewhat compared to the upper watershed, the range of dissolved inorganic nitrate + nitrite-N levels at the lowermost site (#12; RM 1.5) in the late 1980s was 1.50 to 2.60 mg/L. These levels are well above the regional average of 0.930 (USEPA 2000). Dissolved ortho-phosphate levels at this station ranged from 0.085 to 0.250 mg/L in the 1988/1989 study, which represent normal to high phosphate enrichment.

Dissolved ortho-phosphate levels of 0.090 mg/L and dissolved nitrate + nitrite-N levels of 1.10 mg/L measured in 1993 (USGS 1993) are near the average values reported by the USEPA for the region (USEPA 2000). The N:P ratio for these two components is 11:1. The mass ratio implies a slight enrichment source for nitrogen in the Douglas Creek basin, implying algal growths would be limited by phosphorus.

The Foster Creek Conservation District collected nutrient data from one location in the mainstem of Foster Creek in July 2001 and from one location in the East Fork, the West Fork and in the mainstem of Foster Creek in 2002. Total phosphorus and nitrate + nitrite-N concentrations in the Foster Creek basin generally were low to moderate, less than 0.130 and 0.540 mg/L, respectively (**Table 9-6**). These values are in the range of or less than the mean summer value for the region (USEPA 2000). One high phosphorus value of 0.380, nearly 4 times the regional average was recorded in the mainstem of Foster Creek during August of 2002. For the most part, these values do not indicate a level of concern with nutrient enrichment, the samples are collected in flowing water and represent ambient concentrations following upstream plant uptake. An abundance of periphyton and algal masses have been observed in the flowing stream channel of Foster Creek, suggesting growing conditions are sufficient for good development of aquatic plants.

Total Kjeldahl Nitrogen (TKN) is a measure of organic levels of nitrogen. The measured levels were typically low in the Foster Creek basin, with the exception of some very high organic nutrient loading during late spring and early summer in all three of the monitored stream reaches in the Forster Creek basin during 2002. Both the West and East Forks supported the highest organic nitrogen levels; 1.5 to 1.6 mg/L respectively. Although the levels remained relatively high, some dilution was apparent in the mainstem of Foster Creek as organic nitrogen concentrations were cut in half; 0.8 mg/L.

The level of available information is too sparse to quantitatively assess nutrient conditions in local streams. The only areas of concern were noted in the headwater region of Douglas Creek, the observed plant growths in Foster Creek, the associated dissolved oxygen fluctuations and the high seasonal level of inorganic nitrogen throughout the Foster Creek basin.

11.1.2 AQUATIC ECOLOGY

A detailed summary of the late spring 2001 and 2002 macroinvertebrate surveys is incorporated in Appendix B and summarized in Section 9.3.2 above. Indices indicating water quality concerns for various streams are itemized below.

Foster Creek. Macroinvertebrate community indices in Foster Creek indicate a relatively high abundance of organisms but a low diversity of species, suggesting chronic habitat disturbances. Short-lived taxa and burrowers prevalent in the samples indicate the disturbance is routine. The data were unclear if the disturbance was primarily related to temperature increases, sediment accumulation, low streamflows, channel characteristics, or other water quality health issues. It is possible the signal from invertebrate community data in Foster Creek mainstem is a combination of many of the factors mentioned above, showing the integrated nature of the biological response.

West Fork Foster Creek. While the West Fork of Foster Creek supported a relatively high macroinvertebrate density it possessed only a moderate diversity of species. This finding suggests some level of stream disturbance is occurring in this stream. Such disturbances may be related to warm water temperatures, fine sediment accumulations, low streamflows, or other water quality problems.

East Fork Foster Creek. The East Fork of Foster Creek had the lowest macroinvertebrate density, the second lowest number of total taxa and EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera: taxa tied with Sand Canyon and Rattlesnake Creeks) of the eleven streams surveyed. Only one long-lived taxa was found in East Foster Creek. These results indicate water quality and habitat conditions are degraded in East Foster Creek. Warm stream temperatures may be depressing stonefly taxa richness. The dominant functional feeding group in East Foster Creek totaling 35 percent was comprised of filter feeders. This value is an indicator of slow-moving water. It may also suggest high nutrient levels and an abundance of floating algae.

Pine Canyon Creek. The community data indicate relatively low to moderate abundance of organisms. Nevertheless, Pine Canyon Creek supported high numbers of taxa and a high level of fish food items (EPT taxa). There was very little evidence of sediment accumulation influencing the benthic invertebrates, perhaps due to a combination of groundwater inputs and channel gradients, which are slightly steeper than in other local streams. As a result, any fine sediment present is not settling on the streambed. The high level of clinging organisms implies open spaces and surfaces free of fine sediments. The overall B- IBI rating of 31 for benthic invertebrates indicates relatively good water quality and habitat conditions exist for macroinvertebrate community development compared to the other streams surveyed.

Blue Grade Draw. The temporary seasonal irrigation return flows in Blue Grade Draw do not support diverse and robust macroinvertebrate communities. This system is not highly conducive to aquatic biological production.

Sand Canyon Creek. This stream supports low densities, low taxa richness, and low EPT as preferred fish prey items. Short-lived life cycle taxa dominate, and the prevalence of burrowers appears to be an adaptation to flow cessation and sediment deposition. The primary habitat concern in this creek is stability of streamflows, as the temporary seasonal irrigation returns do not support diverse, long-lived and robust macroinvertebrate communities.

Rock Island Creek. The macroinvertebrate survey data indicate good overall water quality and habitat conditions, consistent with a spring-fed drainage system. The data provide supporting evidence for stable streamflows, low sediment accumulations, relatively cool water temperatures, and good overall water quality.

Douglas Creek. The macroinvertebrate data suggest Douglas Creek supports one of the highest taxa richness and EPT taxa richness values of the sites sampled. The B-IBI (Benthic Index of Biotic Integrity) metric score of 31 was the highest (tied with Pine Canyon and McCartney Creeks) of the eleven study stream reaches. A general lack of stoneflies, however, may be related to chronic disturbances or seasonally warm water temperatures at this location. The data imply that Douglas Creek exhibits good water quality, good aquatic productivity, and stable streamflow conditions. These conclusions are relative in nature and are based on the sample size of eleven local area streams. In a regional comparison, Ecology sampled Douglas Creek at Alstown in 1993 and reported a B-IBI score of 23 based on a low level of taxa and EPT richness values and numeric dominance by a few species. They concluded its habitat condition was slightly impaired when compared to a reference site in lower Crab Creek, Washington (Ecology 1995). The 1993 site in Douglas Creek was well upstream of the surveyed reach in 2001. Since it supported a stream flow of only 0.2 cfs in bedrock habitat the resulting biological community data are not comparable to the information gathered during the 2001 survey, except to indicate habitat conditions are generally better downstream for macroinvertebrate production.

Rattlesnake Creek. Rattlesnake Creek, upstream of the confluence with McCarteney Creek, had a moderate number of taxa, but the second lowest EPT richness of the eleven streams. This creek supported only 1 intolerant (water quality sensitive) species and only 2 long-lived species, suggesting a moderate level of habitat disturbance. Overall, Rattlesnake Creek was highly vegetated and contained minimal flow during 2002. It is possible these conditions were not conducive to the considerable macroinvertebrate production. The B-IBI metric score of 19 indicates an obvious level of impairment and an M-HBI score of 5.6 suggests fairly significant organic loading in the stream. This stream does not seem to provide a diverse and robust macroinvertebrate community.

McCartney Creek. McCartney Creek contained the highest macroinvertebrate density and taxa richness, the highest B-IBI score of 31 (tied with Douglas and Pine Canyon) and the second highest EPT abundance of the eleven sampled stream reaches. McCartney Creek contained three intolerant taxa, and five long-lived taxa. These results indicate that habitat is relatively healthy and undisturbed in this stream system.

Coyote Creek. Although Coyote Creek had relatively low macroinvertebrate densities, it possessed the second highest total taxa richness and the highest EPT richness values of the study streams. In addition, the number of long-lived taxa richness was the highest. The high relative abundance of clinger taxa indicates little influence of fine sediment deposition in Coyote Creek. These macroinvertebrate data suggest habitat and water quality conditions are good relative to the other sampled streams.

11.1.3 PHYSICAL CONDITIONS: SEDIMENT

Indices indicating sediment concerns for various streams are itemized below.

Channel Bank Stability. Results from the Stream Reach Inventory/Channel Stability Evaluation (SRI/CSE) performed in the WRIAs 44 and 50 study streams indicate the survey reaches support generally fair to good stability ratings. There were few visual indicators of channel instability at the eight survey reaches. Excessive bank erosion or failures were present on most of the streams where riparian vegetation was lacking, but such features did not dominate any specific reach. Channel migration was present in alluvial fan areas where tributary streams enter the Columbia River floodplain. Although all survey reaches received either a good or fair stability rating, on a comparative basis Blue Grade Draw supported the most unstable channel condition rating of the eight surveyed reaches.

Wolman Pebble Count. Pebble counts are often used to classify substrate composition in gravel-bedded streams. The median diameter (D_{50}) and the diameter of the 84th percentile (D_{84}) of 100 stones counted along a random transect in riffle habitat are values used by many scientists to characterize bedload transport in gravel-bedded streams. One pebble count sample was collected within each of the surveyed stream reaches, with the exception of Blue Grade Draw and Moses Coulee.

The relatively high frequency of fines [< 6 mm (0.24 in.)] and the low median particle size distribution in Sand Canyon and Coyote Creeks, when compared to the other creeks, suggest the geology of these basins is a concern related to the generation of fine sediment loads in the creek. Sand Canyon Creek is aptly named. It traverses a historic complex slump failure that contains abundant fines, silts, and aeolian sands. The lowermost reach of Coyote Creek also traverses a historic slump that likely failed at the bedrock outcrop. Additionally, much of this area may be in a historic floodplain of the Columbia River. The low gradient portion of the creek is presently reworking these sediment loads as reflected in the pebble count data. Channels dominated by fine sediments tend to have lower productivity of salmonid fishes and aquatic macroinvertebrates than stream reaches with somewhat larger sediment sizes.

Although the frequency of fines and the D_{50} in Foster Creek are generally consistent with the other samples, the D_{84} (44.9mm; 1.8 in.) and D_{95} (64.0mm; 2.5 in.) represent the lowest particle size class distributions in the survey. The Sand Canyon Creek riffle substrate size distribution looks similar to that of Foster Creek. These results are consistent with the parent geology in each basin that provide considerable fine sediment inputs to the creeks.

Foster, lower Coyote and Sand Canyon Creeks apparently do not have the transport capacity to clear the small material from the streambed. The sediment deposition in these creeks is apparently overwhelming the capacity of the streams to transport the fines downstream.

Conversely, Pine Canyon, upper Coyote and Rock Island Creeks consist of relatively larger size classes in the riffles than the other sampled streams and an interesting mix of small (D_{35}) and large (D_{95}) particle sizes. These results are, likewise, consistent with the parent geology in each basin and indicative of stream channels with somewhat limited transport capacity.

11.2 WATERBODIES WITH HABITAT CONCERNS

11.2.1 ANADROMOUS FISH ACCESS

In general, the topography and landforms near streams entering the Columbia River naturally limit the potential available fish habitat for spawning and rearing in the WRIAs. The high plateau of the Columbia Basin breaks off sharply near the canyon walls of the Columbia River, creating (1) very steep, cascading stream reaches through intergorge canyons, and (2) extensive alluvial floodplains at the mouths of these streams as the channel gradient flattens near the Columbia River. Low summer streamflows often travel through the alluvial fans below the surface, restricting fish access and rearing capabilities. Steep stream gradients also are not conducive to anadromous fish production.

Blockages to the upstream and downstream migration of anadromous fish species were found in all of the streams surveyed to date. Man-made structures, including a dam in Foster Creek (RM 1.03) and irrigation control structures and road culverts in Blue Grade Draw (RM 0.27) and Sand Canyon Creek (RM 0.35), limit the potential for further upstream migration. Migratory blockages in the form of dry stream channels were noted in all other streams surveyed, as evidenced in Pine Canyon Creek downstream of the SR 2 Highway Bridge (RM 0.0 to 1.23); in Blue Grade Draw and Sand Canyon Creek during the periods when the irrigation water is terminated; in Rock Island Creek upstream of the springs near RM 0.52; and in Moses Coulee downstream of the confluence with Douglas Creek (RM 0.0 to 16.7). It is possible many of the flow blockages are natural conditions that have historically existed in the WRIAs. Further Level 2 study effort with respect to historical flow regimes, especially in Moses Coulee, will be necessary to complete the assessment.

The presence of anadromous salmonid fish use in two streams, Foster and Rock Island Creeks, was confirmed during 2001. Two other streams, Sand Canyon and Moses Coulee, had limited observations of anadromous salmonid use, 15 to 20 years ago. The remaining two streams, Pine Canyon Creek and Blue Grade Draw, have the potential for anadromous fish access and at least temporary use. An assessment of the waterbodies in relation to the potential access for anadromous fish is presented in **Table 10-2**.

Foster Creek. Foster Creek is accessible year-round to anadromous salmon and steelhead trout migrating through the Columbia River up to Chief Joseph Hydroelectric Facility. Summer-run steelhead trout were observed spawning in the creek between RM 0.28 and 0.98 during late May 2001, and young-of-the-year juvenile trout reared in the anadromous fish section throughout the summer, low flow season. These fish have access upstream to a steep cascading stream section complete with numerous bedrock falls just short of an approximately 35 ft. high dam built in a tight bedrock constriction near RM 1.03.

Streamflows, measured at the dam site during the summer of 2001, were continuous but low, ranging between approximately 1 and 4 cfs. Base flows occurring during the month of August were in the vicinity of 1 cfs. A series of springs along the middle and west forks and the west side of the mainstem of Foster Creek support continuous flow.

The man-made barrier to anadromous fish passage on Foster Creek is apparently at the location of a historic natural block. As such, any consideration of facilities to accommodate upstream fish passage would be considered enhancement rather than habitat restoration. Given the open riparian canopy and heavy silt load in Foster Creek, we do not recommend assessing upstream fish passage conditions at this time.

Pine Canyon Creek. Pine Canyon Creek is not accessible to anadromous fish species because of subterranean streamflows across the alluvial fan. There is a lack of surface water downstream of the SR 2 Bridge to its confluence with the Columbia River (RM 0.00 to RM 1.23) except during extreme storm events. The condition of the channel indicates it transports peak stormwater flows only, and that the recurrence interval is greater than on an annual basis. The quality of the water and habitat is considered relatively good for aquatic production upstream of RM 1.23, but providing sufficient water volumes to allow anadromous fish passage across the alluvial fan appears problematic. We found no historical evidence to support the prior use of Pine Canyon Creek by anadromous fish species.

Blue Grade Draw. Blue Grade Draw is a drainage system immediately south of the SR 2 crossing of the Columbia River on the Douglas County side in East Wenatchee. It is supported entirely by irrigation return flows of water withdrawn from the Wenatchee River. Surface waters flow annually from March through October. It is dry the balance of the year. Luxurious riparian vegetation lies along the stream channel since surface waters flow continuously during the growing season. The channel is accessible to anadromous fish species during this period, but actual use has not been documented. Adult fish passage across the fan may be difficult at certain streamflows.

Streamflows from the upstream drainage basin are directed to the north of the SR 2, such that when the irrigation water is terminated the channel remains completely dry. Thus, water flow begins at the irrigation structure at RM 0.27 during the irrigation season, flows underneath SR 2, and daylights on the south side at RM 0.23. The downstream channel is poorly defined. Water runs over roots and masses of grass through thickets of riparian willows as it winds its way past the Loop Trail and onto a short, spongy alluvial fan with a multiple network of rivulets and into the Columbia River. Enhancing access for the production of anadromous fish species does not appear worthwhile, given the generally poor habitat conditions (high stream temperatures, low aquatic productivity, and poorly defined channel) for supporting fish production.

Sand Canyon Creek. Sand Canyon Creek is also supported by irrigation return flows during the summer months. Water from the irrigation ditch is siphoned off at RM 0.54 and allowed to run in the stream channel to SR 28 (RM 0.35), where it is recollected. A portion of the flow is distributed to local orchards adjacent to the stream by an irrigation manifold while the balance of the water continues downstream in the channel to the Columbia River. Without the irrigation water, this channel would be typically dry during the early spring. It remains dry until periods of intense rainfall fill the channel. Anadromous fish generally have access upstream to the SR 28 road crossing and irrigation manifold at RM 0.35. However, no fish were observed during our 2001 field surveys. Flows ranged between approximately 0.5 and 3.0 cfs, with the lowest flows recorded during the month of August.

Rock Island Creek. Summer streamflows in Rock Island Creek during the drought year of 2001 ranged roughly between 0.2 and 2.8 cfs at a gauging station located near the pumphouse at RM 0.17. These streamflows are supported by a man-made spring near RM 0.52. The spring offers a baseflow of around 0.5 cfs during July and August, but its contribution declines to around 0.1 to 0.2 cfs in September and October.

The channel upstream of the spring is essentially dry beginning in early spring each year. As such, anadromous fish species potentially have year-round access from the confluence upstream to the spring (RM 0.00 to 0.52). During habitat surveys in late-May 2001, young-of-the-year chinook or coho salmonid fry were observed rearing in the creek near its confluence with the Columbia River at RM 0.04. Spawning habitat is available in the creek in small amounts along the alluvial fan downstream of the SR 28 Bridge (RM 0.08) and sporadically throughout the creek up to approximately RM 0.44. Whether the observed juvenile fish were the offspring of adults spawning in Rock Island Creek or were from other areas upstream in the Columbia River Basin during the fall of 2000 could not be determined.

Moses Coulee. Moses Coulee is composed of glacial outwash from the Missoula Floods. Porous alluvial materials fill the entire width along the valley bottom between the canyon walls. Although the upstream drainage basin is large, no water flows in the mainstem Coulee a majority of the year. Many years can occur between storms that have sufficient water volumes for surface water streamflow. It is likely, the surface water summer streamflows were historically low and that most of the stream flowed at subsurface levels. The condition of the channel surface downstream of the highway bridge indicates it currently transports peak stormwater flows only, and that the recurrence interval for surface water flows is greater than on an annual basis. Small, base flow conveyance channels etched between the very wide storm terraces are limited, suggesting surface waters flow within the porous alluvial materials at all times except during the largest floods.

As a result, anadromous fish did not have access to Moses Coulee in 2001 and have not had access for a number of years. The channel observations indicate it may have been more than three years ago when there was sufficient water to provide any surface water stream flow in the coulee. Other than dry stream channels, there are no known physical barriers to upstream fish migration. WDF and WDG documented anadromous fish use at time in Moses Coulee during the 1970s and 1980s in the lowermost 1.8 RM of the Coulee. Further assessment is needed to determine the relationship between upstream water sources and their expression as potential surface water stream flows in Moses Coulee.

11.2.2 PHYSICAL CHANNEL ASSESSMENT

Channels were typed in the anadromous fish reaches according to gradient, channel, and valley confinements to describe the channel transport process; and other physical characteristics available for anadromous fish habitat formation. Channel bank stability assessment was performed using the USFS SRI/CSE method.

Foster Creek. Although an abundance of spawning gravel exists and the majority of active steelhead spawning was observed in this reach, high levels of fines were noted in the streambed. The embeddedness of dominant substrate particles with fine sediments was rated at or higher than 50 percent in most observations. The pebble count data imply the stream is currently being overwhelmed with sand-sized sediment and the current stream power is not sufficient to transport the sediment volume. Since steelhead trout are spring spawners, the embryos incubate in the gravel on the descending limb of the hydrograph. This life history strategy reduces the likelihood of adverse siltation effects on embryo development. Nevertheless, current levels of siltation could reduce the flow of oxygen, making reproduction success less likely than in a stream with lower levels of fine sediments. Filling of interstitial spaces with fines will also reduce the amount and diversity of invertebrate prey species available for rearing fry, and will reduce the level of refuge space for cover from predators and high flow events. As a consequence, rearing life-history stages will likely be produced at relatively reduced rates compared to streams with lower sediment levels.

Pine Canyon Creek. Although coarse sediment is prevalent in the Pine Canyon Valley, high levels of fine sediment accumulations were not observed in the channel. This observation, in addition to the channel stability and pebble count survey data, suggests the stream is capable of transporting the fine materials. Spawning, rearing, and food production should not be compromised as a result of the fine sediment levels noted in Pine Canyon Creek.

Blue Grade Draw. This water conveyance system does not appear to have a large sediment load. Headwater sources of sediment have been cut off because streamflows from the upper basin have been redirected to watercourses to the north, and the irrigation flow is fairly free of fines. However, the channel is poorly defined and its SRI/CSE rating is the poorest of those sampled in 2001.

Sand Canyon Creek. High levels of fines and a very small D_{50} in the grain size analysis indicates this stream is generally not capable of transporting the fine sediment load. The parent geology is contributing substantial fines, silts, and sands to this system. The sediment load is likely having an adverse influence on the fish production potential in Sand Canyon Creek compared to streams with less sediment loading.

Rock Island Creek. High levels of fine sediment accumulations were not observed in the channel, likely because of the spring-fed character of the stream. Spawning and rearing habitat and food production should not be compromised as a result of fine sediment levels noted in Rock Island Creek. The present frequency of pools in Rock Island Creek is consistent with pool-riffle channels under low large woody debris (LWD) levels that occur in the creek (Montgomery and Buffington, 1993).

12.0 RECOMMENDATIONS

This assessment was completed using both existing data and data collected as part of this project. However, data gaps remain in many areas of the assessment. Although the level of understanding is likely to never reach a perfect state, the recognition of the magnitude and context of these gaps is critical to a decision-making framework. The data gaps vary in their level of importance to the study. The data gaps considered most important are addressed with recommended studies. This chapter includes: (1) recommendations for ongoing study effort under Level 2 of the watershed assessment, (2) stream prioritization, (3) monitoring recommendations, and (4) conservation recommendations.

12.1 DATA GAPS AND RECOMMENDED FUTURE STUDIES

Based on water quality, water quantity, and habitat data presented in this report, the following data gaps with corresponding recommendations for ongoing study effort under Level 2 of the watershed assessment have been identified:

- The Level 1 assessment identified the Moses Coulee sub-basin as using the highest percentage of available water. However, this analysis included only a rough estimate of groundwater inflow from other basins because no existing information is available on this source of water. Given that 70 percent of the total discharge from the WRIAs is groundwater, the groundwater inflow to the Moses Coulee sub-basin is likely significant and the high use numbers inaccurate. We therefore recommend a hydrogeologic analysis leading to further refinement of the water balance in the Moses Coulee sub-basin. These data could also be used to develop a groundwater flow model to estimate impacts of new water rights appropriations on existing wells and surface water in this basin.

- Not all water rights allocation data are available from the WRATs database. Only 50 percent of the claims information is populated. Hand entering claims information would increase the accuracy of water rights estimates.

- Water usage is a small percentage of water rights within the two WRIAs, suggesting that many of the water rights are unused or underused. These rights should be evaluated to allow for continued growth.

- The irrigated agriculture data used for this project was collected in 1997 and does not include the Colville Reservation or many smaller parcels within the WRIAs. Irrigation accounts for 90 percent of water use within the WRIAs so accuracy of this value has a direct effect on the water balance.

- All water use has been assumed 100 percent consumptive following the Department of Ecology protocol, even though a large percent of septic tank effluent likely returns to the groundwater system. Including septic returns would not likely alter the water budget significantly though. If septic tanks in the basin are generally for domestic use (maximum of 5000 gpd), septic returns would only account for about 3 percent of the water budget.

- Stream discharge records remain minimal and ongoing flow monitoring should continue to establish inter- and intra-annual variability of streamflows.

- The recharge/discharge analysis was completed on a conceptual basis using GIS methods. These analyses should be field checked to increase accuracy.

- Irrigation was estimated using GIS coverage digitized from an aerial photograph by Douglas County. However, there is no information on whether the source of irrigation is surface water or groundwater. Estimation of irrigation source would allow the refinement of the water balance to separate available groundwater and available surface water, rather than combining the two parameters as has been done in this assessment.

- There is an insufficient record of local stream discharge volumes to establish instream flow setting objectives. We recommend simulating long-term hydrographic records based on regional data (see Appendix F, Instream Flow Study Recommendations). Hydrologic studies to simulate a monthly long-term hydrograph should be initiated. The hydrologic data developed from this process should be used to develop daily, monthly, and annual flow records and to predict flow levels during wet, average, and dry years.

- The macroinvertebrate work performed during 2001/2002 provides a useful screening-level assessment of recent water quality and habitat conditions in the creeks. Unless stream conditions change, substantial modifications to the overall conclusions are not expected with the addition of further macroinvertebrate sampling. This type of study effort is labor intensive and expensive. The immediate value of ongoing macroinvertebrate data collection program is unclear. If other streams are of interest to the Planning Unit, macroinvertebrate screening-level assessments are a recommended tool to assist in water quality and habitat evaluations.

- Water quality data remain in short-supply in the WRIAs. Seasonal *in situ* monitoring of temperature, DO, pH, and conductivity is recommended to gather more data and develop a more thorough characterization of water quality on all mainstem streams. If situations of a high level of aquatic plant growth become obvious, initiate seasonal nutrient monitoring to identify if the waters are enriched with nitrogen or phosphorus. Specific water quality sampling is recommended on Foster and Douglas Creeks to help identify habitat quality concerns (see below).

- Insufficient information exists on stream channels north of the Columbia River in WRIA 50. Most of the channels entering the section of the Columbia River downstream of Chief Joesph Dam are steep, seasonal, and are not known to offer habitat for anadromous fish utilization. Waterbodies upstream of Chief Joseph Dam currently support resident fish only and they were not included in the original streams surveyed in 2001 for potential anadromous fish use. However, a cursory habitat and water quality assessment of Coyote Creek occurred in 2002 (as reported herein), until the Colville Tribe concluded it was not in their best interest to continue participation in the watershed planning process.

12.2 STREAM PRIORITIZATION

Anadromous fish species protected under the Endangered Species Act (ESA) are currently using stream reaches in Foster and Rock Island Creeks. These two streams should receive the top priority for future study effort. Both streams are spring-fed, providing continuous, year-round streamflows. Habitat conditions in Foster Creek appear to be more degraded than in Rock Island Creek, and they could benefit from further assessment activities. Although upstream of migratory fish barriers, the West and East Forks of Foster Creek should continue to be reviewed for their ultimate influence on the mainstem reach of Foster Creek.

There were periods 15 to 20 years ago when Moses Coulee supported surface water streamflows and offered seasonal production of anadromous fish species documented below RM 1.8 in the Coulee. Stream flows through the Coulee appear to be related to the volume of groundwater entering Douglas Creek in the vicinity of Pegg and Mohr Canyons. Douglas Creek supports perennial stream flow in the canyon reach, but looses surface water flow across its alluvial fan. Additional study is needed to determine the dynamics of the groundwater source and if groundwater recharge can be enhanced. Habitat concerns for these four creeks are summarized and potential action items to consider for each issue are listed in **Table 12-1**.

Substantive action items for the rest of the streams surveyed during 2001 and 2002 are not recommended. Whereas McCartney, Coyote, Pine Canyon and Douglas creeks offer relatively good habitat conditions for fish production, they historically and currently support resident trout species. Providing access for anadromous fish species is problematic. Conserving habitat features for resident trout and other aquatic species in the WRIAs remains an important consideration, but it is given less priority under H.B. 2514 grants unless the resident species are listed under the ESA. Given the volume of water and the perennial nature of Douglas Creek, this resident fish stream receives a secondary level priority for future study effort.

Although a good volume of water flows year-round in Coyote Creek, further work on this stream is not recommended. Under advice of legal council, the Colville Tribe has discontinued participation in the watershed planning process and no longer allows access to their land for this purpose. McCartney and Pine Canyon creeks support very low volumes of perennial-flowing surface water in discontinuous stream reaches. These creeks receive a third priority level for study effort.

Habitat conditions in Rattlesnake Creek upstream of the confluence with McCartney Creek, Blue Grade Draw and Sand Canyon do not appear to be conducive to salmonid fish production because of very warm stream temperatures, inconsistent streamflow regimes, and a general lack of robust aquatic productivity. Further assessment in these stream systems is not recommended.

12.3 MONITORING RECOMMENDATIONS

We recommend the following water quantity, water quality, and habitat monitoring programs be established in WRIAs 44 and 50:

- Continue monitoring daily streamflows and water temperatures in Foster, Pine Canyon, Rock Island, and Douglas Creeks. Initiate such monitoring in other creeks as warranted.
- Locate discharges from springs that contribute to perennial surface water flows in the mainstem of Foster Creek.
- Monitor dissolved oxygen (DO) and nutrient and conductivity levels in the mainstem and both forks of Foster Creek to improve the understanding of the diurnal and seasonal nature of potential low DO concentrations.
- Initiate a routine observation program of periphyton and algal growths through the summer months in the anadromous stream reach of Foster Creek and correlate their presence with trends in water quality data.
- Initiate snorkel surveys to monitor juvenile fish rearing in the anadromous reaches of Foster and Rock Island creeks and in the canyon reach of Douglas Creek. Such effort will help determine species composition, seasonal timing, relative growth and abundance of salmonid fish species as well as general overall health of juvenile fish with respect to habitat limitations in the creeks. This information would be used to help fine-tune stream-specific life-stage periodicity information and to establish a seasonal flow schedule.
- Establish channel cross-sections and initiate physical habitat data collection to assist in the establishment of instream flow regimes in Foster, Rock Island and Douglas Creeks under the Ecology Instream Flow funding grants.
- Assess and model groundwater levels in Moses Coulee to ascertain the relationship between surface and groundwater flows in the Coulee.
- Following the conceptual approach outlined in Appendix F, Instream Flow Study Recommendations, it is recommended the Planning Unit initiate a sequential process for the development of minimum instream flows under an Ecology Instream Flow Study Planning Grant. The instream flow study recommendations include the following items:
  - Proceed with field studies to help establish instream flow needs as a top priority, on:
    - Foster Creek
    - Rock Island Creek
  - Determine if instream flow establishment is appropriate for:
    - Douglas Creek

  - Delay establishment of flow regimes on all other intermittently flowing streams until resource conditions or flow requirements suggest a future potential assessment would be warranted.

- Establish a subcommittee (or use the scope of work subcommittee) to specifically address the technical details of initiating an instream flow study. The study could benefit from a formal definition of the purpose for setting flows and a vision for the desirable outcome (Step A ISF Scope of Work). Setting goals and objectives for the project is one of the most important steps. All parties in the Planning Unit should be aware of and, hopefully, agree to the study elements. This aspect will minimize future disagreements about the study's approach. Once goals and objectives have been identified in a consensus manner, the appropriate analytical methods and data collection techniques can be selected to address the issues.

12.4 CONSERVATION RECOMMENDATIONS

We recommend conservation activities be established in WRIAs 44 and 50 for current and future needs and development. Many of these recommendations may fall under NRCS or FCCD jurisdiction.

- Be good stewards of the surface water expressions that contribute to perennial streamflows.

- Conserve, protect, and enhance riparian vegetation along stream courses, specifically in Foster and Douglas Creeks and generally throughout all perennial-flowing streams in both WRIAs.

- Encourage soil conservation measures in the headwater regions of Foster and Douglas Creeks by applying agricultural Best Management Practices (BMPs) to farms with exposed soil close to stream channels. Investigate further use of conservation reserve programs on farm areas with soil erosion problems.

- Encourage on-farm water management and water conservation activities in the inland areas that use groundwater for irrigation. The water management activities could include audits of existing irrigation systems to determine efficiencies and potential improvements; use of soil moisture sensors; use of irrigation seheduling programs and real-time crop water use data published by the USBR Agrimet network and Public Agricultural Weather System (PAWS); and constructing upgrades to irrigation systems to improve their efficiency.

- Re-vegetate the draws that are gullying in the East Fork of Foster Creek.

- Devise a plan for livestock and wildlife watering that minimizes erosion and damage to sensitive channel areas.

- Continue work to identify and minimize channel head cuts in the Foster Creek Drainage basin.

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