APPENDIX B

NACHES RIVER BASIN REGIONAL SETTING

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LOCATION

The Naches River lies east of Mount Rainier in the south-central part of Washington State and drains nearly 90,000 acres of the eastern side of the Cascade Range. It is the largest tributary to the Yakima River, which drains a sizeable part of the eastern Cascades before joining with the Columbia River near the Tri-Cities (Richland, Pasco and Kennewick), Washington. The upper Naches watershed is primarily drained by the American, Bumping, and Tieton Rivers. The mainstem Naches River upstream of the Bumping River confluence is known as the Little Naches River, and comprises the geographic headwaters of the basin. The project area extends from the mouth of the Naches River, River Mile (RM) 0.0, upstream 3.75 miles and is located along the northern boundary of the City of Yakima.

GEOLOGY

The geology of the Naches basin is roughly split between the western Cascadian (higher elevations of the basin) and the eastern Columbia Plateau rock types (lower basin elevations). Rock types in the higher, mountainous areas include basalt, andesite, volcanic flows, and intrusive and metamorphic rocks (SCS, 1985; Kinnison and Sceva, 1963). These rocks, with the exception of isolated areas of more recent volcanic flows, are older than those found in downstream areas of the basin. In the lower basin, the Yakima Basalt Subgroup (the younger flows of the Columbia River Basalt Group) originally flowed out from long fissures, spreading out across most of the region and leaving the land surface very flat. The Yakima Basalt laps onto the older Cascadian rocks and pinches out west of the study area. Through time, these basalt flows were deformed, by folding and faulting which created long southeast-trending ridges. In areas flanking the eastern Cascade foothills light-colored tuffaceous sandstone, siltstone and conglomerate rocks called the Ellensburg Formation overlie the basalt ridges (the project area is located in such an area). The Ellensburg Formation sediments are derived from rocks of the Cascade Range and are the youngest of the three formations.

Physiography

The physiography of the Naches Basin is strongly influenced by the geologic history of the region, particularly large scale geologic forces. The western portion of the basin lies within the Cascade Range, an uplifted, mountainous area (including active volcanoes, such as Mt. Rainier) that has been thoroughly dissected by erosion. Permanent snowfields and glaciers exist in some of the headwater areas. Large-scale geologic processes also influence the lower basin's physiography. The regional folding of the Columbia River Basalt was slow enough that the Yakima River was able to cut through the folded basalt ridges and maintain its course. The narrow openings in these ridges where the Yakima and other rivers cut through are locally known as "gaps" (e.g. Union Gap, Selah Gap). The upper project boundary is located at one of these features commonly known as the Naches Gap. Here the Naches River has cut a narrow opening in the basalt as it flows on through the project area to its confluence with the Yakima River.

The synclinal valleys and tributaries to the Yakima (synclinal valleys being formed by regional geologic folding that creates a formation that is concave upward), including the Naches River and the Naches Valley, are characterized by extensive stream alluvial deposits, shallow depth to groundwater (SCS, 1985), and extensive land conversion for orchard and other irrigated agriculture. Long, smooth-sided anticlinal basalt ridges separate these large, broad valleys. The mainstem of the Naches River follows a conspicuous northwest/southeast trend for nearly 30 miles because of regional folding.

Geologic Units in the Project Area

The hills along the left bank of the river define the northern boundary of the Naches River floodplain through the entire project reach, and are composed of two geologic units. Both of these rock units belong to named basalt flows (the Grande Rhone Basalt and the Wanapum Basalt, respectively). These flows and one other (the Saddle Mountain Basalt) comprise the Yakima Basalt Subgroup, which in turn is a part of the Columbia River Basalt Group.

Tgn2: Grand Rhonde Basalt: upper flow; normal polarity

This relatively resistant bedrock comprises a significant portion of the hillslope on the left bank of the river through the study reach. This geologic unit is composed of unnamed basalt flows, divided into magneto-stratigraphic units based on dominant polarity. The basalt is nonporphyritic to very sparsely plagioclasephyric, generally fine-grained and petrographically nondistinct (Walsh, 1986).

Twf: Frenchman Springs Member (of the Wanapum Basalt)

This relatively resistant bedrock makes up a lesser portion of the left bank hillslope of the river through the study reach. Rock is a medium to coarse-grained highly to very sparsely plagioclasephyric basalt. Fresh exposures are gray to black; gray to reddish-brown on weathered surfaces. Thin sedimentary interbeds are common. Lower flows may be pillowed at base (Walsh, 1986).

The valley bottom and river floodplain of the Naches River through the project reach is composed of stream alluvium (Qal) and terrace deposits (Qt) (Walsh, 1986). These deposits are comprised of stream-transported silt, sand, and gravel and may also be comprised of some glacial outwash (SCS, 1985). From the Naches Gap downstream to the mouth of Cowiche Canyon near RM 3.3, stream alluvium comprises the entire valley bottom along the right bank. Terrace deposits begin along the right valley wall downstream of Cowiche Canyon (Figure A-3). These deposits are distinguished from the alluvium by position, height above the lower alluvium, and ostensibly by age (the terrace deposits being older than the recent alluvium). Downstream of Pecks Canyon, near RM 2.3, the right-bank basalt dips and the wall is comprised solely by Ellensburg Formation. This valley wall begins to dip and trend away from the river, running southeast as the river continues east and stays close to the left valley wall. As the right valley wall continues southeast and eventually dives below the terrace deposits that underlie much of the City of Yakima, both the alluvial and terrace deposits along the river each become wider. Near the current location of the 16th Avenue turnout, stream alluvium deposits (Qal) are approximately 0.75 miles in width (Walsh, 1986).

Faulting in the project area

Two faults influence the geologic setting of the study reach (Figure A-3). North of the river, an anticline (a regional geologic fold creating a formation that is concave down) deforms the basalt on the left bank and creates the prominent ridgeline that runs along the entire left bank throughout the project area. This anticline roughly parallels the course of the river, before crossing the Naches River and its floodplain just upstream of the mouth of Cowiche Canyon (Walsh, 1986). To the south of the river a separate fault runs roughly parallel to the anticline to the north. This second fault lies just to the south of US 12 and heads up the ridgeline south of Pecks Canyon. It is mapped as being concealed by alluvium through the area near US 12 (Walsh, 1986), but is mapped as visible once it reaches the right valley wall.

CLIMATE

The climate of the Naches River basin ranges from alpine, along the crest of the Cascade Range, to arid in the lower valleys. This results in significant variation in winter and summer weather and also between locations within the basin. Precipitation varies greatly depending on elevation and distance from the Cascade Range crest. For instance, Rimrock, located at roughly 3,000 feet elevation and 10 miles from the crest in the Tieton River sub-basin, receives an average annual of 25 total inches of precipitation, with 107 inches as snowfall (SCS, 1985). Precipitation is likely higher in the surrounding peaks of the upper Naches watershed. Downstream, in Yakima (elevation approximately 1,100 feet and roughly 40 miles from the crest), total annual precipitation averages 7 to 8 inches, with 25 inches as snow.

Temperature variation in the basin is somewhat less dramatic. The winter average temperature in Yakima is 32 °F and 29 °F at Rimrock, while summer temperature averages are 68 and 61 °F respectfully. Summer maximum temperatures average about 80 °F, and a record maximum of 110 °F was recorded in Yakima in August 1971.

Climate change effects in the project area

Climatic change over geologic time can be dramatic in terms of its influence on basin-scale erosion, sediment transport, and landscape evolution. For instance, during a glacial period sediment supply to a river can be significantly greater than during an interglacial period. During this transition, a river may switch to a ‘negative sediment balance’ compared to the previous glacial period. The effect of this transition is that rivers tend to shrink into their floodplains rather than expand, creating vast alluvial deposits with an underfit stream. Such a situation could currently be occurring in the Naches system.

APPENDIX C

NACHES RIVER BASIN HYDROLOGY

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NACHES RIVER BASIN HYDROLOGY

The Naches River watershed is 86,136 acres is size, with 52.7 percent (45,394 acres) in the snow-dominated zone, 27.6 percent (23,778 acres) in the rain-on-snow zone, 17.1 percent (14,752 acres) in the highland zone, and 2.6 percent (2,209 acres) in the rain-dominated zone (United States Forest Service [USFS] 1995). The following text, taken from the draft United States Bureau of Reclamation (USBR) Interim Comprehensive Basin Operating Plan (IOP), provides a qualitative description of basin hydrology:

> The Naches River near Naches stream gage (NACW) natural unregulated streamflow starts increasing slowly, mid-October through November as fall precipitation increases and then natural flows will recede to winter conditions as freezing conditions in upper watersheds reduce runoff. It is common to have a rain induced flood event at the end of November or early December, with other major flood events resulting from a rain-on-snow event coupled with a rapid thaw occurring through February. Regulated streamflow is much lower than unregulated conditions and does not show the peaks due to reservoir inflows captured in storage. During the December through February period, the discharge is stable except for rain-on-snow events that formed the short duration, high discharges on a relatively infrequent basis. Regulated winter streamflow is roughly 43 percent lower than natural conditions, and the frequency and magnitude of peak flows is greatly reduced due to reservoir operations for flood control and storage. In March, natural flows will start to increase and continue through late May. Unregulated streamflow forms the average annual peak discharge from April through early June. Starting in April, regulated streamflow is very slightly reduced as irrigation deliveries above NACW begin to increase. Current project practice for flood control operations allows for maximizing storage in late May, early June, and after this time the bypassing of reservoir natural inflows to the river system, returning some of the natural variability to the river system. Beginning mid-June, unregulated streamflow will decline from spring freshet to baseflow conditions by late August. Based on the past 19 years, regulated flow only exceeds unregulated from the start of flip-flop in late August to the end of the irrigation season October 20th, flows are wheeled to meet downstream irrigation demands that were earlier supported from the upper Yakima reach. From early July until late August or start of flip-flop, regulated flows are lower (200 to 600 cubic feet per second (cfs) per day) than the estimated natural unregulated flows. The estimated average natural unregulated flow from mid-August to late October is less than 425 cfs per day. From September 10th through October 20th, streamflow fluctuates very little under natural conditions, but regulated flows rise precipitously from lows in late August (300 cfs or less) to September 10th (1,900 cfs) after flip-flop is in place.

FLOOD FREQUENCY AND MAGNITUDE ANALYSIS

Two gaging stations exist in the Naches River where hydrology data has been collected over a period of time. The Naches at Naches gage, located approximately ¾ mile downstream of the Tieton River confluence, produced the longest data record (86 years). The Naches at Yakima gage, ½ mile upstream from the confluence with the Yakima, produced 18 years of data. However upon evaluating the Yakima gage, we determined that data from this gage was unusable for our purposes. Peak flow records for the two gages indicated that the peak discharge recorded for the Yakima gage was less than the value recorded at the Naches gage for many days of record and often less by thousands of cubic feet per second. This is highly unlikely given the proximity of the gages to one another and the tributary inputs and lack of flood storage between the gages. We evaluated the methods used to collect these data and found that the methods used for the Yakima gage were inconsistent and were taken at numerous locations near the gage. This area has been highly dynamic and the USBR themselves questions the accuracy of Yakima gage data. Therefore, we focused on the Naches at Naches gage for determining peak flows for the project area. Eighty-six years of record were used in this analysis. The United States Geological Survey (USGS) operated the gage from 1909 to 1979, and the USBR began operation in 1985. There are no records from 1980 through 1985, and records are missing from 1913 – 1915. We used a log-Pearson Type III distribution fit to the station as described in USGS' Water-Resources Investigations Report 97-4277, Magnitude and Frequency of Floods in Washington. Because data from the Yakima gage were unreliable, peak flow values from the Naches gage were correlated to the project site using the basin scaling method and exponent values also included in the USGS report. Results from the peak flow analysis of data from the Naches at Naches gage are displayed in Table 1.

Table C-1: Recurrence flows for the Naches at Naches gage.

Recurrence Interval	Discharge (cfs)
1 yr	1109
2 yr	6696
5 yr	10771
10 yr	13955
20 yr	18543
50 yr	22380
100 yr	26586

These data were then correlated to the project site by considering that the basin area at the Naches near Naches gage has a contributing basin area of 941 square miles and the Naches near Yakima gage (located within our site) has an 1,100 square mile basin area, and using the relationship:

$$Q_b = Q_a \left(A_b / A_a \right) ^\wedge {}^{n}$$

Where:

Q_b is the discharge at the project site

Q_a is the discharge from the Naches at Naches gage

A_b is the basin area at the project site

A_a is the basin area at the Naches at Naches gage

n is the regional exponent determined by USGS

The results of this evaluation are presented in Table C-2.

Table C-2: Recurrence flows for the project site.

Recurrence Interval	Discharge (cfs)
1 yr	1249
2 yr	7539
5 yr	12128
10 yr	15713
20 yr	20879
50 yr	25200
100 yr	29936

FLIP-FLOP OPERATIONS

The term “flip-flop” comes from the switch in seasonal water supply for irrigation needs downstream of the Naches/Yakima confluence, switching the water supply source from the upper-Yakima sub-basin to the Naches sub-basin. The upper Yakima River system reservoirs are used to meet irrigation demands downstream of the Naches/Yakima confluence from the beginning of the irrigation season through the first week of September. Beginning the first week of September, reservoir operations throughout the Yakima Basin are transitioned. Irrigation demands downstream of the Naches/Yakima confluence continue to be met but with water stored in the Naches River system reservoirs as flows from the upper Yakima River system reservoirs are reduced.

The current flip-flop operations are the result of the “Quackenbush Decision” initiated for the 1981 irrigation season. In 1980, spring chinook were spawning in the upper portions of the Yakima River during the period that reservoir releases were increased to meet downstream irrigation demands. When these releases were decreased at the end of irrigation season, about 60 salmon redds were identified in the upper Yakima River. A portion of these redds were de-watered as releases were decreased. In October 1980, Judge Justin Quackenbush of the Federal District Court ruled that the USBR must release water from Yakima Project reservoirs to keep redds covered with water. By November 1980, the Court directed the Yakima field office manager to work with fishery professionals to find a way to modify Yakima Project operations to protect the fisheries resource while at the same time providing water for irrigation purposes. An additional mandate was to do so prior to the 1981 irrigation season. This alteration in release magnitude and timing targets a more consistent discharge during spawning activities reducing the likelihood that redds will be de-watered.

IMPACTS OF FLIP-FLOP ON THE NACHES RIVER HYDROGRAPH

A synopsis of impacts to the natural hydrograph of the Naches River is provided in the Draft USBR Interim Comprehensive Basin Operating Plan (IOP) for the Yakima Project (USDI, 2002 DRAFT).

> “The comparison of natural inflow and reservoir discharge reflect a greatly lower (less than 20 percent) than natural flow, but stable outflow during late October and November; with December through March still reflecting a lower outflow (less than 35 percent) than natural, but with more variability due to flood control operations.
>
> “Mid-April through June outflows tend to mirror inflow patterns, but at a reduced quantity (due to storage and flood control operations), with the inflow/outflow relationship coming closest to matching during June as storage is maximized and the natural runoff is peaking. Currently, the maximum discharge releases (2,200 to 2,600 cfs) are made during September 10th through September 30th for irrigation demands. Of the 369,323 acre-feet average annual natural (unregulated) flow generated in the Rimrock basin, 209,373 acre-feet (57 percent) is delivered/released during July 1st through October 20th to meet system demands during the normal period of low natural flows.”

The flip-flop period occurs when unregulated flows would typically be at their annual low (see Figure C-1). Instead, Tieton River flows are up to five times higher than would occur naturally (USDI, 2002 DRAFT). Operation of Rimrock Dam during the flip-flop in early September increases releases from about 650 cfs to over 2,000 cfs. These releases then drop abruptly in mid-October, when the irrigation season ends. Daily mean winter releases from Rimrock Dam rarely exceed 250 cfs from the end of the flip-flop through mid-February. Even then, daily mean releases from the reservoir do not exceed 500 cfs until approximately the first week in May, when snowmelt runoff is beginning to increase and the reservoir is approaching capacity. Under pre-dam conditions flows reached a summer maximum (approximately 850 cfs) during late-June. Discharge then declines through the summer into fall.

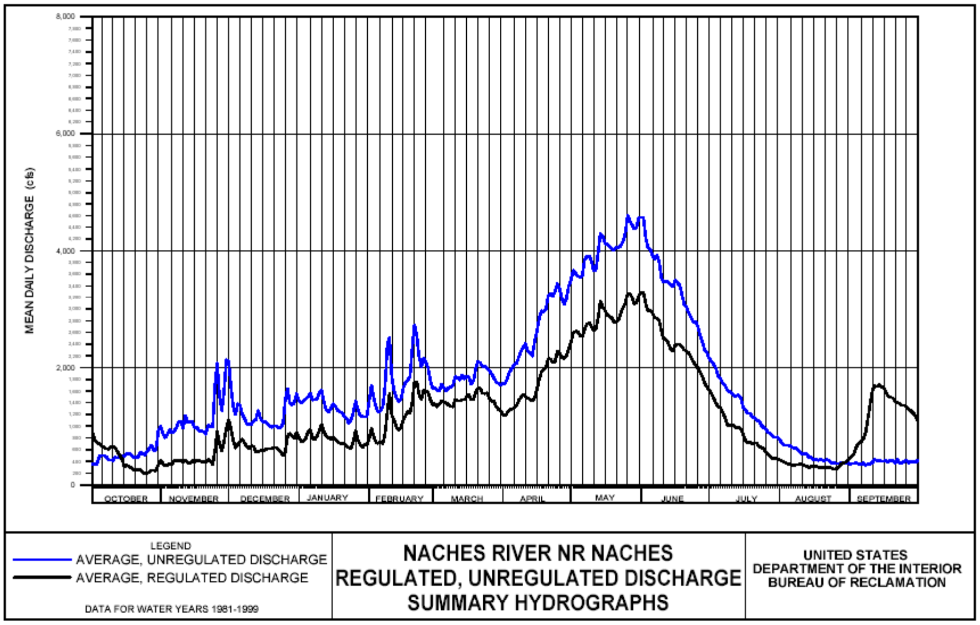

Figure C-1: Regulated and Unregulated Summary Hydrographs for the Naches River. Blue line represents average, unregulated hydrograph; black line represents average, regulated hydrograph. Adapted from the USBR DRAFT IOP, page 6-48 (USDI, 2002 DRAFT).

Potential changes to future flip flop operations

Title XII of the Act of October 31, 1994, Public Law 103-434, Section 1210 (Title XII), directed that the Secretary of the Interior, in consultation with the State of Washington, the Yakima Nation, Yakima River basin irrigation districts, the Bonneville Power Administration (BPA), and other entities as determined by the Secretary, develop an IOP (USDI 2002 DRAFT). The 1994 Title XII legislation provided that an additional purpose of the Yakima Project "shall be for fish, wildlife, and recreation. Also, the existing storage rights of the Yakima Project shall include storage for the purposes of fish, wildlife, and recreation. But, the above specified purposes shall not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts." In Water Year (WY) 1995 Title XII target flows were instituted. Based on our review of documents and hydrologic records, we understand that management of Naches River flows has been consistent since at least 1995 when Title XII was implemented.

In the IOP, improvements to the operations of the Yakima Project are presented and recommendations are put forth to reduce negative impacts to aquatic and riparian ecosystems (USDI, 2002 DRAFT). Most recommendations appear to represent a move toward management of the system that takes an emphasis on supporting flow regimes that "promote the health of riparian habitat." These recommendations appear to be preliminary and arriving at an alternative flow prescription for the Naches River will likely be a lengthy process. However, based on the tone of recommendations in the IOP, it seems apparent that any proposed changes to the flip-flop flow regime will move toward a more natural flow regime where peak and low flow periods more closely resemble pre dam conditions. If such changes are implemented, dam operations should have a reduced impact on the Naches River ecosystem over time.

APPENDIX D

SEDIMENT DYNAMICS IN THE NACHES RIVER BASIN

APPENDIX D

SEDIMENT DYNAMICS IN THE NACHES RIVER BASIN

Sediment dynamics include the supply of sediment from headwater and tributary source areas, the ability of the river to transport sediment (transport capacity), the storage of sediment in the bed and floodplain of the river, and the availability of that stored sediment for erosion and transport during high flow events and channel migration. The supply of sediments from headwater channels is dependent upon the local geology of the drainage basin, but can also be influenced by basin scale changes in erosional resistance that can be induced by fire, logging, or other landuse alterations. The transport capacity of a river system is dependent upon the channel gradient and hydrologic regime. Transport capacity is a main deterministic factor in the channel morphology of a river system, and plays a key role in understanding geomorphic process (Montgomery and Buffington, 1998). The factors affecting sediment dynamics in the Naches basin are highly varied, with different management actions producing results that impact the same sediment dynamic "variable" in opposite ways. For example, historic timber harvest practices and other disturbances have likely increased sediment supply in the basin, while dams have eliminated the sediment supply of tributary rivers. Data quantifying such impacts in the project area are lacking. Subsequently, we based our assessment of these changes on known relationships between the physical processes governing sediment dynamics and the likely response of the system to these changes.

IMPACTS TO HEADWATER CHANNELS

Increased sediment production from timber harvest activities is a known impact in the upper parts of the Naches basin (USFS, 1995). According to a recent report, the upper river basin has been heavily impacted by road building, timber harvest and sheep grazing, influencing the natural vegetation patterns found prior to Euro-American settlement (USBR, 2002 DRAFT). These activities have been shown to increase the production of fine sediment and destabilize stream channels (Reid, 1981; Weaver and Hagans, 1994; Ziemer, 1998). The USFS conducted a comparison of channel conditions in the upper basin using 1962 and 1992 aerial photos for a reach of the upper Naches River (Pinecliff Bridge to the confluence of the Bumping River, nearly 40 miles upstream of the project area) (USFS 1995). The USFS found that bankfull channel width and channel length had decreased, channel gradient increased in some reaches, and there was a decrease in size and number of mid-channel gravel bars. They surmised that these changes were in response to decreased sediment load over time, presumably in response to recovery from early logging. As a result of changes in forest practices instituted in the latter portion of the 20th century, many of the impacts to headwater channels are diminishing.

DAMS

The installation of dams in the Naches Basin has disrupted the longitudinal continuity of the river system, interrupting what has been described as the natural “conveyor belt” of sediment transport (Kondolf, Smeltzer, and Kimball, 2001). In 1910 the Bumping Dam was constructed on the Bumping River, and in 1925, the Tieton Dam was built creating Rimrock Lake (USBR, 2002 DRAFT). By changing the flow regime and sediment transport activity of a river basin, dams can produce adjustments in alluvial channels. The character of these changes is dependent upon altered flow regimes and resultant sediment load alterations. For example much of the sediments that would be transported down the Tieton River are currently being stored in the reservoir, resulting in a sediment deficit in the river downstream of the dam. Such a sediment deficit often leads to degradation of the existing channel and a loss of habitat diversity.

An evaluation of the physical and biological affects of Rimrock Dam and its operations indicates that the lack of bedload transport through the dam site has affected channel morphology and resulted in a decline in habitat complexity (USDI, 2002 DRAFT). Decreased sediment supply leads to a “hungry water” situation where a river downstream of the dam is starved of sediment, and as such has an increased capacity (or “hunger”) to carry sediment (Kondolf, 1997). This typically leads to transport of bed and bank materials that would have been stable prior to dam construction. In the Tieton River, increased erosion and incision has occurred affecting channel pattern and form and the supply of suitable gravels available for salmonid spawning. Spawning gravels have been washed downstream, and neither anadromous nor resident salmonid reproduction has been observed in the Tieton River for decades (USDI, 2002 DRAFT). In addition, aquatic invertebrate populations are depressed, primarily because of winter stranding which occurs when invertebrate habitat is dewatered.

The degree to which the impacts found on the Tieton River propagate downstream into the Naches River is uncertain. Because of the direct connectivity between the two systems, it is reasonable to suspect that the lack of sediment coming from the Tieton River has some affect on the Naches River. Prior to the placement of Rimrock Dam, the Tieton River basin upstream of the dam (comprising roughly 20 percent of the Naches River basin as measured at the confluence of the two rivers) was likely a viable source of sediment to the lower Naches River. One source (B. Watson, Pers. Comm., *as cited in Washington State Conservation Commission [WSCC], 2001*) observed that “from the Tieton River confluence to the Naches River mouth, the wetted channel substrate is composed primarily of large cannon ball-sized material embedded with sands and fines”. However, Watson pointed out that it is unknown to what extent these substrate conditions are associated with flip-flop flows and interrupted sediment transport from the Tieton River. We do not confirm or refute this claim, however during field observations we did note that the substrate in the wetted channel through the study reach is fairly coarse and that exposed floodplain banks contain a greater percentage of fine sediments than newly created bars.

GRAVEL MINING

Gravel mining operations have been extensive along the Naches River, occurring through the project reach as well as through portions of the Naches Valley upstream of the project area (Stanford *et al.*, 2002). Collins (1995, *in Kondolf, Smeltzer, and Kimball, 2001*) examined floodplain gravel mine pits along rivers in Washington that were larger than 3 acres and deeper than the groundwater table. Collins estimated that from River Miles 0-5 of the Naches River (an area extending slightly above the project reach) there have been at least 9 separate floodplain gravel pits totaling 84 acres. This total includes only the larger, three-plus acre pits and represents approximately four percent of the available floodplain area. Most of the gravel mines in the project reach do not appear to have ever been operated as instream pits, but instead operated in floodplain pits outside the wetted channel.

Gravel pits decrease floodplain sediment supply through a direct removal of material, however interaction with subsequent fluvial processes can also have adverse impacts. Because floodplain pits are typically located within the active floodplain, channel migration can result in the river moving into these areas and "capturing" the gravel pit. Pit capture effectively transforms floodplain pits into instream pits. Based on our interpretation of sequential aerial photographs, at some point in the 1980s the Naches River flowed through and occupied the location of a former gravel pit. When pit capture occurs, all of the river's bedload delivered to the pit will for a time become stored in the former pit. This typically results in a propagation of incision upstream and downstream of the pit (Galay 1983*, in Kondolf, Smeltzer, and Kimball, 2001*). This interruption in bedload transport can also have a dramatic affect of the aquatic habitat in the channel as ecological conditions degrade.

To prevent pit capture, revetments and levees are commonly constructed between active channel and the pits. This confines the active channel cutting it off from its floodplain. We observed such actions in historic aerial photographs of the project reach. Through time, decreased floodplain width and increased bank revetment along a river promotes channel incision and a simplification of the channel network. Because of this, floodplain pits in close proximity to the active channel are often accompanied by channelization.

SUMMARY

The supply of sediment to the Naches River has been reduced by the installation of dams in the headwaters and the construction of levees and riprap cutting off access to sediments stored in the floodplain. Sediment supply in some portions of the basin has likely increased because of road building, timber harvest, and grazing. These impacts have reportedly been reduced in the upper headwaters, but it is likely that development activities lower in the basin continue to affect sediment inputs. The balance between the sediment deficit induced by the dams and the sediment generated by development is currently uncertain. However, the ability of the Naches River to transport sediment has been reduced because of the altered hydrology. This is not to say that sediments no longer move through the Naches system, but that it is likely that the residence time (time sediment spends in the system before being transported out) has increased.

APPENDIX E

RIPARIAN FOREST DYNAMICS IN THE NACHES RIVER BASIN

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RIPARIAN FOREST DYNAMICS IN THE NACHES RIVER BASIN

The importance of riparian zones for river and ecosystem health has been well established (Gregory, *et al.*, 1991; WSCC, 2001). Riparian zones provide a source of food and nutrients to the river ecosystem, add hydraulic complexity, and create diverse habitat both for aquatic and terrestrial species. They also function as the main source of large woody debris (LWD) in streams, a habitat component lacking in the lower Naches River (WSCC, 2001). Through time, the extent and quality of riparian forest along the Naches River in the project area has declined. Early accounts of forest conditions indicate extensive cottonwood gallery forests, interspersed with occasional conifers and other deciduous species. Forest in the project area has decreased in extent and conifer species have been almost entirely eliminated.

HISTORIC RIPARIAN FOREST CONDITIONS

Information regarding the condition and composition of vegetation along the rivers of the Yakima Basin prior to Euro-American occupation is minimal. Harner (in Snyder and Stanford, 2001) provides the only comprehensive synopsis of the subject, and draws heavily from the accounts of early surveyors sent to the Washington Territory between 1853 and 1855 to determine routes for future railroads (U. S. Senate Executive Documents, 1860). These early accounts relate that the first cottonwoods (*Populus* spp.) began to line the Yakima River 40 miles up from its confluence with the Columbia River, near the present-day town of Prosser. Some Ponderosa pine (*Pinus ponderosa*) was interspersed in these stands. The number of conifers increased in density with distance upstream, as evidenced by the passage: “You pass up the Yakima seventy miles before you reach the building pine, although cottonwood is found on its banks sufficient for camping purposes” (U. S. Senate Executive Documents, 1860; Book 1). River Mile (RM) 70 on the Yakima River is located over 40 miles downstream of the Naches/Yakima confluence, giving the indication that conifers were indeed a component of the riparian zone on the lower Naches River. Further, the productivity of the floodplain and surrounding land was identified as improving with distance upstream: “Towards the mountains, the valleys, both of the main Yakima and of its branches, improve much in appearance and agricultural capacity…”(*ibid.*). Working their way upstream of the Yakima Valley, the first major tributary and valley the surveyors would have encountered would have been the Naches River and the land now occupied by the City of Yakima. From these descriptions cottonwood seems to be the dominant species, but the role of the conifers should not be discounted. Cottonwood gallery forests interspersed with other deciduous species and occasional Ponderosa pines would have combined with more open areas in recently abandoned channels and wetlands to provide a rich habitat mosaic across the floodplain, benefiting terrestrial, avian and aquatic species. Upon erosion into the river, these forests coupled with LWD inputs from upstream forests and floodplains would have been capable of creating large wood jams, integral in creating multiple flow paths.

IMPACTS AND FOREST CHANGE THROUGH TIME

Cumulative impacts to riparian forests along the Naches River through the study reach have been extensive. Based on our interpretation of aerial photographs, floodplain and associated riparian forest in the year 2000 had declined to approximately 56 percent of that observed in the 1927 photograph. From the photographs, it appears much of this loss is the result of direct removal of forest for agricultural expansion and road construction. This is, however, an admittedly short data set relative to assessing pre-impact forest extent, and likely provides a conservative estimate of forest loss. Based on the 1927 aerial photographs, it is very probable that approximately 70 years of early land use practices (such as land clearing and draining for agriculture) had already reduced historic floodplain and riparian forest by the time of the 1927 photograph.

Contemporary changes to the flow regime of the Naches River because of dam releases have likely had a negative effect on the riparian forest. Dams and altered flow regimes of rivers in North American have been documented to negatively impact the health of bottomland trees (particularly cottonwoods) and riparian vegetation communities as a whole (Friedman *et al.*, 1998; Mahoney and Rood, 1998; Merigliano, 1996; Rood and Mahoney, 1990; Scott *et al*, 1996). Cottonwood and willow species are among the first to establish along a river, and without successful cottonwood seedling establishment, riparian forests cannot be maintained (Snowden, 2002; Rood and Mahoney, 1990). Based on the specific alterations to the natural hydrograph of the Naches River and the fact that cottonwoods are an important component of the riparian forest along the river, two important system impact mechanisms emerge: 1) reduced recruitment due to scour and inundation of seedlings, and 2) stress and mortality of mature trees by inundation.

Reduced recruitment

Recruitment of cottonwoods typically occurs when seed release coincides with recession of spring flooding, providing bare, moist, mineral soil in open areas along the active channel needed for germination (Rood and Mahoney, 1990). This seed must land at an elevation such that the seedling roots will be able to keep pace with and “follow” the declining water table as the adjacent river discharge declines. Soil texture and distance from the channel are additional variables influencing water availability, root growth, and recruitment success. After initial germination, if river discharge decreases too quickly the subsequent drop in the local water table will cause the roots of the seedlings to desiccate and the tree will die. Alternatively, if seed dispersal occurs prior to peak runoff, the increasing discharge will typically scour the lower-elevation seedlings. Annually, seed ripening and release dates occur during a fairly regular time period within a given bio-region, but vary widely across different bio-regions (i.e. from the coastal, temperate Puget Sound region to interior, eastern Washington). As such, seed dispersal is relatively constant within a given watershed, and therefore flow regime is the critical variable for successful recruitment. With every water year different in terms of the timing and magnitude of spring peak-runoff, extensive recruitment does not occur every year, and may occur only once every ten years (Bradley and Smith, 1984, in Rood and Mahoney, 1990). Therefore, recruitment lost during a single recruitment year because of discharge alterations induced by management activities may be more significant than it at first appears.

To illustrate the potential impacts of altered flow regimes on the Naches River, it is useful to use the recruitment "box model" (Mahoney and Rood, 1998). The model (Figure E-1) uses a typical annual hydrograph to identify the temporal (red, vertical bounds of the box) and spatial (yellow, horizontal bounds) extremes of viable recruitment. Dates to the left and right of the box are outside the seed dispersal "window", and locations above and below the box will lead to desiccation or scour, respectively. This model is typically "calibrated" to an individual river system by recording timing of maximum seed dispersal and surveying the elevation relationship between numerous plots of established trees and channel morphology (required to establish stage/discharge information for scour and desiccation).

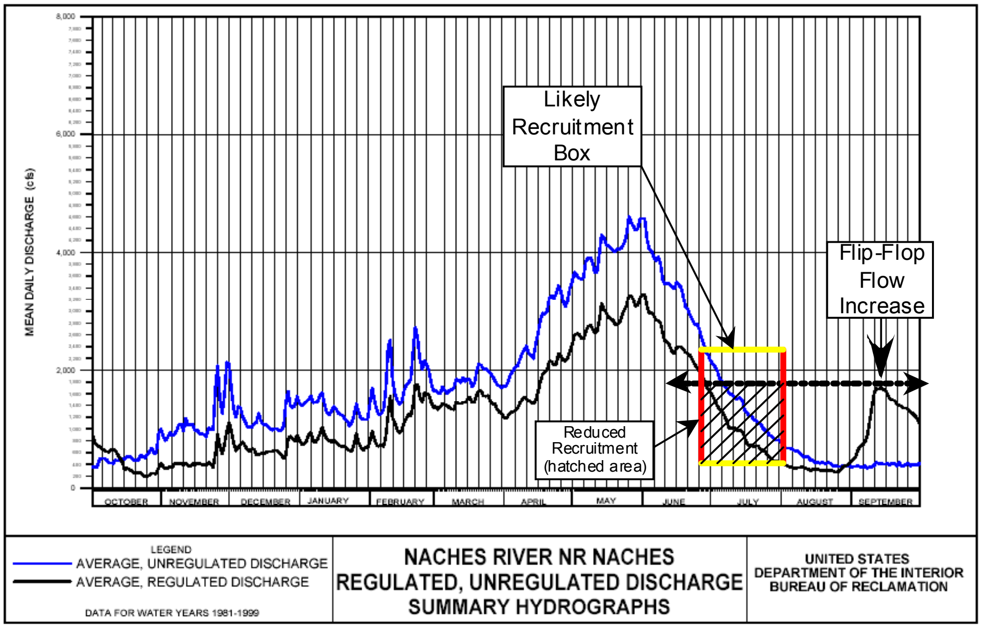

Figure E-1: Hypothetical Recruitment Box Model for Black Cottonwood on the Naches River. Red and yellow bars create the " recruitment box." The red bars bracket the period of seed release. The yellow bars bracket the discharge occurring during the seed release period. Discharges in the box correspond to stage on the banks, and thus the yellow bars correspond to the elevation limits of recruitment. Hatched area depicts portion of recruitment elevations that are inundated by flip-flop flow increases. Base figure adapted from the USBR DRAFT IOP, page 6-48 (USDI, 2002 DRAFT).

Though less accurate than a fully calibrated model (which would be necessary for determining alternative discharge prescriptions) a non-calibrated version can be used for the Naches River to illustrate the impacts of the flip-flop operation. According to Roe (1958), seed release can begin in late-May in the Puget Sound region, but closer to the Naches River, seed release in western Idaho was found to begin as late as mid-July. An optimistic, best-case seed dispersal window for the Naches River of just over a month is portrayed in Figure E-1. Required river stage or discharge for successful recruitment, the horizontal bars in Figure E-1, is extremely dependent on the site (bank angles, soil textures, root growth rates, etc.). Based on the seed release period, the Naches River model displays a range of nearly 2,000 cubic feet per second (cfs), corresponding to a foot or more of stage at many locations in the reach according to our observations. Because of the coarse nature of sediment on the floodplain, this seems an optimistic range of recruitment elevations, and is included to make the illustration as robust and inclusive as possible (i.e. an extremely slow, steady decline of the hydrograph, allowing for recruitment at very high elevations. This would be extremely advantageous for trees recruiting in that year, because scour from moderate discharge in subsequent years would be less important).

The impacts of flow regulation and the flip-flop on young-of-the-year cottonwoods can be illustrated by considering the timing and magnitude of the flip-flop discharge increase as shown on the black (regulated) hydrograph in Figure E-1. During seed fall, discharges are lower than natural (blue, unregulated hydrograph), causing recruitment (the entire “box”) to occur at an unnaturally low elevation. Regardless of other alterations to discharge (such as decreased peak flows) this places seedlings at a lower elevation, making them more susceptible to scour, inundation, and burial by sediment. Subsequent to their lower recruitment elevation, the flip-flop increases discharge in the Naches River to nearly 2,000 cfs. At the time of the flip-flop, seedlings are typically less than two months old, are not well rooted, and are highly susceptible to scour. Inundation of juvenile cottonwoods on other rivers has been found to be an important way in which recruitment is hampered (Roberts et al., 2002 DRAFT; Snowden, 2002). A possible additional impact of the flip-flop includes reduction of suitable substrate for recruitment (a coarsening of the bed and floodplain), but is thus far quantitatively unsubstantiated.

INUNDATION MORTALITY

The extent and timing of floodplain inundation and/or root saturation can have detrimental impacts on riparian stands. If conditions are too saturated, these individuals may die (Crivelli et al., 1995). The number of days of flooding a tree can survive depends upon the species, age, size, and gender of the tree; the depth, temperature, and clarity of the water; and the timing of inundation relative to the growing season (Gill, 1970; Whitlow and Harris, 1979; Stevens and Waring, 1985; Dawson and Ehleringer, 1993). The initial effect of inundation on all plants is through the root system. The waterlogged soil becomes anoxic and this leads to oxygen stress and eventual elimination of the primary root system. (Hosner, 1960; Nilsson and Berggren, 2000). Mortality from prolonged inundation can also be caused by exhaustion of energy reserves (Friedman and Auble, 1999). Timing and duration of flooding is an important aspect of inundation mortality. Tests on yellow poplar (Southeastern Forest Experiment Station, 1958 *in Hosner, 1960*) showed that submergence during the dormant season had little or no effect, but inundation during the growing season resulted in significant adverse effects in as few as three days, with only 5 percent of the test individuals alive after 14 days of inundation.

From our field observations during the flip-flop and subsequently from cursory surveys within the forest in the study area, it appears that the trees along the Naches River are very susceptible to inundation during the growing season. During our observations we found few viable cottonwood seedlings, and only small areas of emergent-sized trees (up to ¾ inch diameter). In addition, there were numerous dead mature-sized (18-30 inches diameter at breast height [dbh]) trees along the river. Our observations during the flip-flop (discharge approximately 2,000 cfs) indicate that the discharge increase inundates entirely or thoroughly saturates the roots of many trees directly adjacent to and nearby the edge of the active channel (Figure E-2). At some locations within the project area, the entire available floodplain was either inundated or saturated to a level above the root structure of the riparian vegetation.

Figure E-2: Photograph of floodplain saturation of a cottonwood stand during flip-flop flow conditions and recently fallen trees at edge of bank.

SUMMARY

In a healthy, undisturbed river system tree mortality would be a part of the normal disturbance regime and important for dynamic, healthy ecosystems (Naiman, *et al.* 1992). However, the river ecosystem in the Naches River is impacted (floodplain and associated riparian forest reduced by approximately 57 percent [WSCC, 2001]) and managed (altered flow regime). As such, inundation mortality influenced by unnatural conditions results in a significant impact to the system. Decreased recruitment combined with a reduced floodplain and diminishing mature forest will perpetuate substantial decline in riparian forest. As older cottonwoods die off younger individuals will not be present in sufficient numbers to replace them. With no changes in management, future forest conditions could be expected to trend toward one dominated by older cottonwoods, with numerous dead and dying trees along older channel margins, and increasing dominance by other species such as willow and alder. Based on our observations of age classes, this transformation may already be well underway. Loss of varying age classes of cottonwoods in the Naches riparian forest is significant, as they are a keystone species for forest succession for this and many other rivers (Cepello, 1991; Rood and Mahoney, 1990).

APPENDIX F

SUMMARY OF THE SALMONID HABITAT LIMITING FACTORS ANALYSIS

APPENDIX F

SUMMARY OF THE SALMONID HABITAT LIMITING FACTORS ANALYSIS

The Habitat Limiting Factors study conducted for the Yakima River Watershed is a comprehensive document outlining the conditions that limit the ability of habitat to fully sustain populations of salmon, including all species of the family Salmonidae (WSCC, 2001). The document reviews difficulties of fish access in the river, floodplain modifications, the conditions of the channel, substrate and riparian, water quality and quantity, all as they relate to salmonid habitat. Not all of these habitat-limiting factors apply to the project area, hence selected habitat limiting factors are discussed below.

The Naches River system supports spring chinook, fall chinook (presumed presence), summer steelhead, and bull char (also known as bull trout), as well as several other salmonid and non-salmonid species (WDFW, 1998). Several of these species are listed as threatened under the federal Endangered Species Act (National Marine Fisheries Service [NMFS], 2003; United States Fish and Wildlife Service [USFWS], 2003):

- Spring chinook—listing not warranted
- Fall chinook—listing not warranted
- Steelhead—listed threatened
- Bull char—listed threatened

Despite the Federal ESA listing status (spring Chinook not listed), the Washington Department of Fish and Wildlife (WDFW) found that spring chinook populations in the Naches River are depressed based on chronically low escapement (p. 169; SASSI, 1993). The same report describes summer steelhead populations in the Naches River as one of five distinct populations identified in the Yakima Basin and that steelhead populations are depressed based on chronically low wild spawner escapement. Both species are native stocks sustained by wild production.

FLOODPLAIN AND CHANNEL CONDITIONS

An important function of floodplains is to provide aquatic habitat. For instance, spring chinook and coho salmon juveniles often use the sloughs and backwaters of floodplains to over-winter since this provides a refuge from high flows (WSCC, 2001). Additionally, rearing on the inundated floodplain itself has been demonstrated to offer increased growth for juvenile salmonids, significant over that which would be attained in the mainstem of the river (Sommer, *et al*., 2001; Sommer, *et al*., 2000). Floodplains and side channels with complex roughness elements can help to dissipate and disperse water energy during floods by allowing water to escape the main channel and inundate the terrestrial landscape. Similarly, instream channel conditions, such as suitable spawning substrate, large woody debris (LWD) and complex cover, are important for salmonids.

Loss of floodplain in the Naches River watershed during the 20th century is estimated at 57 percent, with 30 percent of the loss occurring between 1915 and 1965 (WSCC, 2001). Despite this loss, the section of the Naches River from approximately the Naches Canal Diversion (River Mile 18.4) to the mouth has been identified as crucial for the long-term survival and recovery of salmon in the Yakima watershed (Stanford, *et al.*, 2002). It is in fact one of the top four reaches in the entire Yakima watershed, having been evaluated and ranked based "on natural habitat heterogeneity, productivity, current and historic use by anadromous salmonids, and restoration potential." (Snyder and Stanford, 2001 DRAFT, *as cited in WSCC, 2001 p. 109*). Despite the fact that this area ranks among the best habitat in the Yakima basin, it has sustained significant anthropogenic impacts. Some of the channel and floodplain impacts identified in the Habitat Limiting Factors Inventory include (WSCC, 2001):

- Loss of floodplain
- Decreased channel sinuosity
- Channel constriction downstream of the Naches Gap
- Coarsened bed, possibly as a result of flip-flop operation.

RIPARIAN VEGETATION AND LWD INPUTS

According to the Limiting Factors Inventory, riparian forests along the Naches River have undergone a significant decline by direct removal for construction of dikes and roads from the mouth to the confluence of the Tieton River (WSCC, 2001). With the loss of floodplain along the Naches River estimated at over 57 percent and our estimate of reduction in the project area of nearly 50 percent, direct removal of forest along the river has been a significant mechanism of loss. Additionally, changes in flow regime coupled with floodplain constriction appear to have decreased recruitment of cottonwood trees (the keystone riparian tree in the lower basin) and may be impacting the health of existing trees. With existing mature forest size reduced and recruitment of younger trees declining, forest size and health along the lower Naches River is continuing to decline. Based on our observations, we surmise that the trend of declining recruitment, failing health, and increased mortality in riparian trees in the study area will likely continue without management intervention.

Large woody debris inputs to the system have also been impacted. A survey of LWD from Pinecliff Bridge to the Bumping River confluence (USFS, 1995, *as cited in WSCC, 2001*) found all reaches to be well below the Wenatchee National Forest and USFS Region 6 LWD standards. The limited presence of LWD in the mainstem river was suspected to stem from active removal of LWD from the Naches River from Cottonwood Campground to the Bumping River confluence following a flood in 1976/1977. Based on our observations, the project area receives the majority of its LWD from the riparian stands surrounding upstream reaches and tributaries that are transported to the site.

Water Quantity

Alterations to the natural annual hydrograph affect the lower Naches River (Figure E-1). The Limiting Factors Inventory identifies low flows during the winter and early spring, and prolonged high and fluctuating flows in the summer as the major factors affecting anadromous salmonid production in the mainstem Naches River (WSCC, 2001). In the winter, low instream flows in the lower Naches River significantly impact natural reproduction of spring chinook and steelhead (WDFW, 1997a, *as cited in WSCC, 2001*). The lower Naches River is subject to extreme changes in discharge with adverse impacts to salmonids. "Sudden increases in flow cause fish to vacate feeding territories and migrate to new areas, increasing competition and stress, reducing growth, and increasing the likelihood of mortality, either through predation or being displaced to unsuitable down-river habitat" (CBSP, 1990, *as cited in WSCC, 2001 p. 191*).

Recommended actions from the Habitat Limiting Factors Inventory

Based on the limiting factors outlined above, the Habitat Limiting Factors Inventory identified the following action recommendations for the Naches River pertinent to the project area and this management plan (WSCC, 2001):

- Protect/preserve ecological integrity of critical floodplain reaches
- Where possible, remove/relocate roads currently in the floodplain to outside the floodplain
- Develop and implement a short-term LWD strategy to restore LWD presence and habitat diversity
- Ensure that floodplain hazard planning and strategies consider and adequately protect salmonid habitat

APPENDIX G

HYPORHEIC ZONE OF THE NACHES RIVER

APPENDIX G

HYPORHEIC ZONE OF THE NACHES RIVER

Several studies have surmised that the hydrologic cycle in the Yakima Basin, including the lower Naches basin, can be characterized as having extensive exchange between the surface, hyporheic and groundwater zones (Kinnison and Sceva, 1963; Ring and Watson, 1999; Stanford *et al.*, 2002). In the Naches Basin, this exchange occurs mainly in the alluvial Naches Valley and floodplains, functioning as a hydrologic buffer by distributing the energy of peak flows and moving cool, spring melt water out onto the floodplain (Stanford *et al.*, 2002). This seasonal inundation would recharge the shallow, surficial aquifers; a process that could potentially exist well into summer due to extent and longevity of the Cascade snow pack (Ring and Watson 1999). Prior to land use impacts, base flow of the Yakima River and tributaries during mid to late summer was derived and sustained almost entirely from groundwater and natural lake storage (Parker and Storey, 1916). As such, the groundwater recharge processes are particularly important in the maintenance of base flows. As summer progressed and air temperatures increased, these processes would have provided areas of cooler thermal refugia, and maintained warmer winter temperatures, preventing or reducing the risk of anchor ice (Kinnison and Sceva 1963, *in Stanford* et al., 2002). As early as 1963, Kinnison and Sceva noted upwelling to the Naches River just upstream of the Naches Gap, providing the first documented indication of a dynamic exchange between surface water and groundwater on the Naches River.

Stanford *et al.* (2002) conceptualize each of the Yakima sub-basins as being downwelling (losing surface water to the hyporheic and groundwater systems) at the upstream end, and upwelling (gaining surface water from the ground water and hyporheic) at the downstream end, similar to situations described for other rivers (e.g., Stanford and Ward, 1988; Tockner and Schiemer, 1997). Upwelling is typically driven by the decreasing size of the sedimentary aquifers (i.e. the constriction caused at the Naches Gap) forcing groundwater back into the river and other surface water features (i.e. spring brooks, irrigation ditches, etc) (Stanford *et al.*, 2002). Eleven monitoring wells were installed in the Naches Valley, upstream of the Naches Gap (Stanford *et al.*, 2002). The spatial focus of this research was upstream of the project area, however some of the findings provide a larger context into which the project area can be placed. Results from monitoring during the summer of 1999 show that all areas of the floodplain studied had some degree of subsurface connectivity with the main channel, and water table elevations "fluctuated dynamically with river stage." (p. 113, Stanford *et al.*, 2002). Even with only three transects in the Naches Valley, the study confirmed the conceptualized idea of upwelling at the end of the sub basin just above the Naches Gap.

Based on the conceptual model of surface water downwelling at the upstream end of a subbasin and anecdotal descriptions of subsurface conditions, a characterization of hyporheic and groundwater flow in the study area can be made. Groundwater and hyporheic water is confined by the Naches Gap and upwelling is known to occur just upstream of the project area. Downstream of the Naches Gap, the valley is constricted along the left bank of the river by the anticlinal basalt structure that comprises the hillside. Alluvium in the valley floor is at least 1,000 feet deep, based on the depths of the City of Yakima's diversion wells (Dave Brown, Pers. Comm, 2002), and the mouth of the Naches enters the Yakima River in a relatively unconfined area. Along the right bank and through the alluvium in the floodplain south of the river, groundwater movement can occur both parallel to the direction of flow (east) and away from the river (southeast). Several studies have indicated that water from the Naches River flows directly under the City of Yakima, contributing to shallow aquifers in the area (Dave Brown, Pers. Comm, 2002). In the larger context, the Yakima/Naches confluence occurs just downstream of the Selah Gap on the Yakima River, an area of known upwelling. Based on the conceptual models of valley constriction and surface/subsurface water exchange (Stanford and Ward, 1988; Tockner and Schiemer, 1997; Stanford *et al.*, 2002), this reach of the Yakima (beginning at Selah Gap) is likely downwelling as well. In fact, this downwelling is thought to occur as far as four miles downstream of the confluence (Stanford *et al.*, 2002).

In summary, it is likely that the entire study area is losing flow to groundwater and the hyporheic zone. This water likely travels south and east under the city of Yakima and may return to surface flow in the upwelling area just upstream of Union Gap (in the Yakima river system). This synopsis is consistent with patterns identified in the Yakima Basin where downwelling occurs upstream of the gaps (i.e. Selah Gap, Union Gap, etc.) and upwelling reaches are found just upstream of the gaps.

APPENDIX H

FLOODPLAIN AND CHANNEL DYNAMICS

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FLOODPLAIN AND CHANNEL DYNAMICS

Evaluation of channel and floodplain conditions was based upon our site investigations and review of existing information. As previously discussed, little information in the form of scientific data or reports was available for the project area. This resulted in a dependence on the evaluation of the available historic aerial photographic record (1927, 1947, 1968, 1992, 1993, 1998, and 2000), maps, and professional interpretation of ongoing fluvial process using little preexisting data.

Basin position and local geology and topography play a role in physical processes and the resultant channel patterns found in river systems. In many river systems, headwater channels are steep and slope gradually decreases moving toward the bottom of the basin. Reaches of alluvial river systems where gradient declines from that of upstream reaches are characteristically depositional reaches (Montgomery and Buffington, 1998). Channel pattern in these depositional reaches are typically more dynamic both spatially, through channel migration and avulsion, and temporally, in that the river may change from one configuration to another and back again.

The project reach is in the lower Naches Valley. While it is clear that headwater channels in the Naches are steeper than the project reach, LiDAR data available to us indicate that the gradient through the study reach is not appreciably less than the reach from the Naches Gap upstream to the confluence with the Tieton River (Figure H-1). The best-fit line and R^2 value displayed in Figure H-1 highlight that the elevation drop per mile from the confluence of the Tieton to the Yakima River is essential equivalent. Based on the similarities in gradient and lack of tributary inputs, we surmise that sediment flux and thereby natural channel characteristics and processes in the project reach were similar to those of the reach from the Tieton River to the Naches Gap.

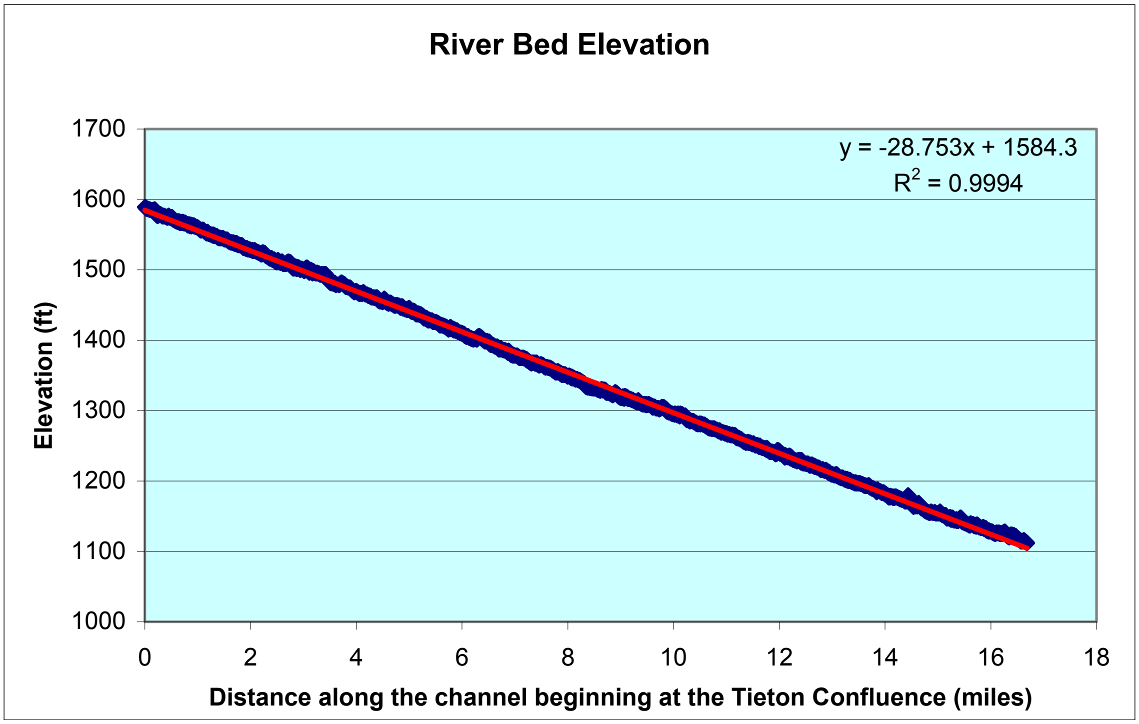

Figure H-1: Riverbed elevation for the Naches River running downstream from the Tieton River confluence.

The Naches Gap, located just upstream of the project area, is a significant geologic feature affecting channel and floodplain morphology in the project area. The gap acts as a constriction point in the valley and during extreme flow events constricts flow and creates a backwater. Because of this constriction, sediment transported into the backwater area from upstream begins to deposit. It is likely that this process is enabled at lower flows than under historic conditions because of the additional constriction of the US 12 highway prism and bridges. As deposition occurs, the river channel can actively move across the floodplain further depositing sediments. The result of this activity is that large quantities of sediments can be stored upstream of the gap during extreme flows. During less extreme flow events sediment stored in this depositional area are often transported downstream through local channel incision and migration. Transport capacity through the constriction of the Naches Gap (and likewise under the US 12 and railroad bridges) is high, hence this localized river segment is a transport reach where sediments from the depositional area upstream and beyond are passed through with no local sediment storage. Downstream of the gap, this high energy is dissipated as sediments are transported. Thus at some point, the river is no longer able to continue transporting sediments at the same rate and deposition begins to occur. This process is compounded by the fact that channel constriction is reduced and flow is dispersed over a greater channel width (historically speaking). Typically, where sediments begin to be deposited bar features are formed and channel migration activity increases. Because of the lack of confinement (the valley and floodplain widen downstream of the gap) and active deposition, these channels segments are typically mobile, contain large bars and/or islands, and have the capacity to develop multiple flow paths. Under these conditions, frequent avulsion of the mainstem (switch from one channel location to another) likely resulted in increased channel complexity and associated habitat diversity.

Present day channel and floodplain conditions in the project reach are much different than historical conditions. The General Land Office (GLO) created a map dated 1866 depicting the mainstem river through the study reach as a meandering channel (Figure H-2) (General Land Office, 1866). It is important to note that details such as the exact width and the extent of all channel features were not typically mapped during GLO mapping efforts. As such, the 1866 map depicts the location of the mainstem channel but does not indicate the location or extent of chute cut-offs, perennial floodplain channels, LWD accumulations, or other complex channel features.

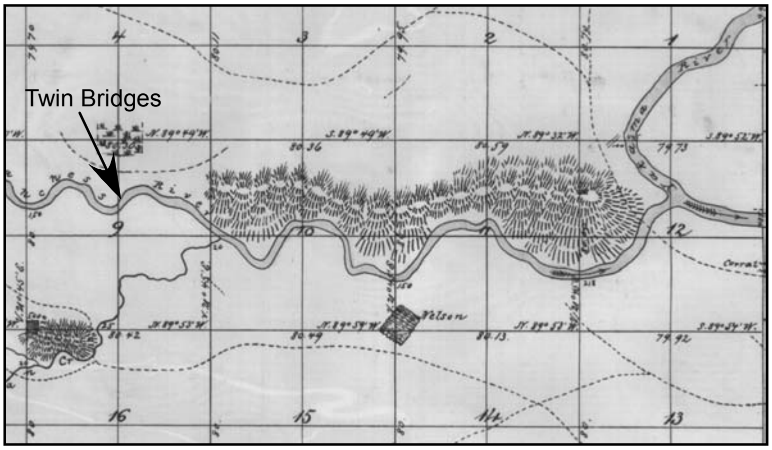

Figure H-2: Portion of the Map of Township 13 North, Range 18 East, Willamette Meridian. (General Land Office, 1866).

HUMAN INFRASTRUCTURE ALTERATIONS TO THE FLOODPLAIN AND CHANNEL

Through the twentieth century, development in the lower Naches Valley progressively encroached upon the Naches River and its floodplain. Numerous structures (bridges, levees, and roadways) and other human infrastructure have encroached on the floodplain and have ultimately locked the channel in place in certain locations. The progression of these events can be identified in the aerial photographic record (Figures A-4 through A-10).

Transportation Infrastructure

Early transportation routes crossed the Naches River near the Naches Gap and by 1927 the river was funneled under roadway and railroad bridges at the gap (Figure A-4). As additional transportation routes were installed, additional bridges were needed. At present a total of four bridges, three for roadways and one for the railroad, cross the river at this location (Figure A-10). On the lower end of the reach, two railroad bridges and three highway bridges cross the river. At most of these bridge locations, rock revetments have been constructed to maintain the river in its current location. These installations are designed to lock the channel in place, preventing bank erosion and channel migration.

In 1972 the US 12 "bypass" project replaced the former state route through downtown Yakima with a four-lane highway located within the floodplain of the Naches River, bypassing the downtown area (Figure A-7). The highway is elevated above the natural river floodplain for nearly the entire length of the project reach and acts as a levee. At the 16th Street interchange, roadway construction has extended into the active channel such that a constriction point that functions similarly to the Naches Gap has been created.

Water Diversions

The development of water diversion systems in the early twentieth century for irrigated agriculture and development of portions of the river's right floodplain into orchards (Figure A-4) have created additional impacts. Two irrigation ditches were initially created using sections of natural side channels (Figures A-4 & A-5). Diversion of water into these ditches was at first achieved by forming the channel bed material into a simple dam. Through time, both the structures and the river have required routine maintenance to maintain a position that allows gravity diversion. At Station 16100 the placement of large rock in the active channel has been required to maintain connectivity with the diversion channel. In the early 1950s, the City of Yakima (COY) installed a Ranney-type domestic water production well at Station 15500, directly adjacent to the current river channel (Figure A-6) (Dave Brown, pers comm, 2002). The floodplain was filled to an elevation roughly 20 feet above the current channel bed, and the pump facility was built atop. This mounded material also extends upstream of the facility and into the active channel such that it creates a channel constriction similar to that of the Naches Gap.

Floodplain Gravel Mining

As further development occurred in the basin, the floodplain became a source for aggregate needed in development. Based on aerial photographs and records related to highway construction, floodplain gravel mining occurred from about 1947 through at least 1972 (Figure A-6). During the relocation of US 12 in 1972, several additional floodplain gravel pits were excavated to provide fill material for the elevated road prism. These pits have now filled with groundwater and are ponds on the floodplain, some of which are isolated from the river by the highway. It is unknown if any instream gravel mining occurred on the Naches River. However, there are several areas within the active channel in the 1968 aerial photograph that are potentially the result of instream activities between 1947 and 1968. The photographic record also indicates that at least one floodplain pit was later captured by the river some time in the 1980s.

Levees

Levees have been placed along the Naches River in the project area for a variety of reasons. In the upper end, levees were placed to prevent flooding of land converted to orchards (Figure A-4). Roads and levees associated with gravel pits are first identifiable in the 1968 aerial photograph (Figure A-6). During the extraction operations, it is likely that smaller, temporary levees were placed to isolate the river from ongoing mining activities. Once gravel was removed and operations ceased, extensive ponds resembling small lakes remained (Figures A-6 through A-10). On larger ponds, where the risk of the river avulsing into the ponds was great, levees surrounding these ponds have been reinforced to prevent avulsion. For instance, at the downstream end of the project area, a levee has been constructed along the right bank of the river that protects two large ponds and continues down to and extends along the Yakima River for additional flood control (Figure A-10).

FLOODPLAIN CONSTRICTION

The cumulative effect of human impacts to the Naches River during the evaluated historical record is a dramatic reduction in floodplain area available to the river for flood conveyance and attenuation and natural channel migration. To help illustrate reduction in floodplain area, we identified 12 locations through the project area and evaluated the available floodplain width from each of the available aerial photos (Figure A-11). For the purposes of this determination, floodplain width was defined as all alluvial surfaces available for inundation and channel migration during a large flow event (approximately equal to or greater than a 100-year event). Hence, roadways, gravel pits, orchards and other human infrastructure that isolates or has been isolated from the floodplain are not considered part of the floodplain in this width measurement.

Table H-1 displays the available floodplain width at each of the 12 locations for each photo year reviewed and the percent decrease since 1927. Average floodplain width in the project area has decreased over 50 percent since 1927. Width changes are smaller in the upper and lower ends of the project reach where early impacts from the railroad and small levees had likely already reduced the available floodplain by the time of the 1927 photograph. The most extensive area of floodplain reduction since 1927 has occurred in the upper-middle portion of the project area (between Station 16000 and 12400). At Station 12400 (Figure A-11), floodplain width has decreased from over 2,000 feet in 1927 to less than 300 feet in 2000.

Table H-1: Floodplain Widths at Selected Locations in the Project Area.

STATION	1927	1947	1968	1992	1993	1998	2000	Percent decrease since 1927
19100	1000	1000	570	250	250	250	250	75%
17100	950	560	600	625	625	625	625	34%
16000	700	500	250	250	250	120	120	83%
15400	800	610	150	150	150	150	150	81%
13850	1100	815	388	310	310	310	310	72%
12400	2015	1821	230	230	230	230	230	89%
10000	870	1150	1100	760	760	760	760	13%
8350	650	730	688	520	520	520	520	20%
6900	1270	750	800	950	950	950	950	25%
5100	530	530	520	350	350	350	350	34%
3150	680	630	630	310	310	310	310	54%
2200	530	530	500	500	500	500	500	6%

Average Floodplain Width	925	802	536	434	434	423	423	54%

The physical effects of reduced floodplain width in the project area include a dramatic reduction in floodplain area available for natural processes such as channel migration. The reduction in available floodplain also affects flood conveyance and reduces the attenuation of floods on the floodplain, forcing more water to stay within the channel. The increased flow depths and velocities within the channel increase stream energy, frequently resulting in channel incision. Once the channel begins to incise, a positive feedback loop may be created where continued incision leads to progressively larger flows contained within the channel. These increased erosional forces lead to further channel incision, and so on. As this feedback loop continues, there is decreasing potential for floodwaters to access the floodplain and increased likelihood of channel degradation.

Diminished floodplain area and inundation can negatively affect ecological processes and biotic components of the river floodplain. When floodwaters are confined to the channel and do not spread onto the floodplain, the important process of nutrient exchange between the river and its floodplain is curtailed. Narrower floodplains result in reduced riparian forest compared to pre-disturbance conditions, and correspondingly less ecological value to the channel and floodplain. Thus when the river begins to erode portions of the riparian forest, ecological loss is more significant than in an intact, undisturbed floodplain. This can be particularly important when channel incision and altered hydrology are potentially limiting the regeneration of riparian vegetation, further exacerbating the decline of floodplain forest.

The relocation of US 12 in 1972 resulted in additional confinement and floodplain reduction in the project area. This was studied by the U.S. Army Corps of Engineers in 1970 when they projected the area inundated by a Standard Project Flood: "the flood that may be expected from the most severe combination of meteorological conditions that is considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations" (USACE, 1970; p. 55). Such a flood is much larger than a 100-year event, and though it is a rare event "…it is a commonly accepted fact that, in practically all cases, sooner or later a larger flood can and probably will occur". A flood of this type for the Naches River was determined to be 83,000 cfs, and the inundated area for this flood is depicted as the dotted area in Figure A-12. Note that it roughly corresponds to the location of terrace deposits in Figure A-3, and supports our supposition that historic floodplain widths are likely much wider than that seen in the 1927 aerial photograph.

The relocation of US 12 was recognized to compound earlier floodplain constrictions in terms of both lateral confinement and in height. Due to the height of the elevated roadway, "the proposed relocation of U.S. Highway 12…[would] limit the extent of overflow for all floods up to and including the intermediate regional flood [essentially the 100-year event] and prevent future loss of orchard farm lands from overbank erosion." (USACE, 1970, p. 21 and p. 46). Based upon US 12 build-out parameters, the inundated area during flooding was predicted as the solid area in Figure A-12. These predictions appear accurate based on aerial photographs of the river during the 1996 high flow event.

CHANGES IN CHANNEL FORM

Using the historic aerial photographic record, we digitized outlines of the wetted channel for approximately the one to two-year event for each photograph or map (Figures A-13 and A-14). When possible, vegetation on mid-channel and lateral bars were delineated relative to density. This was done to evaluate trends in sinuosity and channel complexity and reductions in the channel network and habitat diversity through time.

Reductions in Channel Network and Changes in Form and Process

In the upper half of the project reach, both the form of the channel and its location have become homogenous and stagnant through time as channel sinuosity has decreased, side channels have diminished, and bars in and along the main channel have disappeared (Figure A-13). Station 9000 to 5000 remains the most active segment of the project area even though there has been a trend of decreasing sinuosity and channel complexity in all of the occupied mainstem channels from 1992 to 2000. The GLO map and early aerial photographs depict Station 16000 to 9000 as more closely resembling a true "meandering river" than other segments of the project area. Since that time, it has become the straightest, least dynamic portion of the project area. Stream channels with higher degrees of sinuosity have reduced stream energy compared to straight channels with similar size and channel form. This occurs because the increased distance over which the river travels for a given drop in elevation disperses available stream power over a longer course. Streams that lose sinuosity (for any of a number of reasons) and become straighter, typically have increased stream power and can erode their banks, become incised, and disconnected from their floodplains.

Placement of levees, riprap, and other human infrastructure that limits or halts channel migration can frequently translate to changes in channel type and function (Knighton, 1998). Roughly thirteen thousand five hundred feet of the right bank of the project area has been impacted by the placement of riprap or levees or by floodplain filling, representing approximately 70 percent of the channel length. The affect of this bank hardening and confinement is compounded by the fact that the river flows along a bedrock valley wall along nearly the entire project area. The result of this confinement is that the channel has straightened considerably and channel locations have been stagnant in many areas for over three decades. Subsequently, there has been a transition from a meandering, partially anastomosed channel displayed in the earliest maps and photographs, to an anastomosed channel with less sinuosity in the middle part of the 1900s, and finally to a single thread, relatively straight channel with still further decreasing sinuosity in the last 10 years (Figure A-13).

While sinuosity has decreased and channel type has changed through time, perhaps more important to channel dynamics has been the loss of side-channels and diverse mid-channel bar types and sizes (both key components of complex channel networks) throughout the project area. Complex channels convey flow through multiple flow paths and disperse more energy per lineal foot of channel than do simplified channels. Hence, sediment transport capacity in more complex channel networks is frequently less than in simplified channel networks.

Reduction in Channel Complexity and Aquatic and Riparian Habitat Diversity

Because physical processes create habitat and drive ecological processes, decreased channel complexity and the changes in channel form and process seen in the project reach through time have resulted in decreased aquatic and riparian habitat. Figure A-14 displays the active channel network and all mid-channel and lateral bars that are readily accessible by the river at moderate flows. Figure A-14 illustrates the reduction in mid-channel and lateral bars through time, and the simplification of the channel. Additionally, the density (and based on field observations, the age) of riparian vegetation covering these bars has decreased as well. It is important to recognize that portraying channels as they are in Figure A-14 is an effort to include all possible flow paths and depict them at their “most complex”. This may tend to overstate the complexity and extent of the channel network during low flows. For instance, at low summer flow many of the side channels seen in the polygons for 1992 through 2000 would be entirely dry.

As seen in Figures A-13 and A-14, channel form within the reach has changed through time. Channel planforms are often associated with various bed morphologies, with these bed morphologies in turn providing different types of aquatic habitat. For example, meandering channels are typified by pool-riffle reaches that consist of a laterally oscillating sequence of bars, pools, and riffles resulting from oscillating cross-channel flow that causes flow convergence and scour on alternating banks of the channel (Montgomery and Buffington, 1998). Anastomosed reaches are characterized by multiple flow paths and numerous mid-channel islands that remain stable for significant periods of time. Fish use these pools for holding, feeding and protective cover, the riffles for spawning, and the side channels for refuge during high flows. Other aquatic organisms, such as benthic invertebrates, rely on the substrate and flow velocities for much of their life cycle. Dense riparian areas, either in close proximity to the main stem channel or connected to it by side channels, provide important nutrients and insect drop for aquatic communities.

All channel/bed morphologies provide some degree of aquatic habitat, and at least some basis for ecological process. However monotonous, lengthy sections of one habitat type does not comprise diverse habitat. It is the mixing of these various morphologies within a longitudinal distance of approximately several channel widths that creates this diversity. For instance, much of the straightened channel sections in the project reach have been reduced to what are plane-bed channels that have a relatively featureless gravel/cobble bed. These channel sections were formerly comprised of channel morphologies that contained pools, riffles, and cut off chutes, all within the length of several channel widths. Presently, the Naches River in the project reach has extensive amounts of river channel that are typically termed runs, riffles, glides and rapids. These channel conditions offer little opportunity for juvenile and adult fish to find refuge from higher flow velocities. Based on our observations, habitat diversity, within the reach, is very low.

SUMMARY

Progressive settlement of the Naches Valley and the subsequent installation of human infrastructure have encroached upon the river corridor reducing the floodplain area available to the river for channel migration and attenuation of floods. This confinement and the installation of instream diversions have impacted the configuration of the river channel resulting in the channelization of flow, channel incision, and the degradation of instream habitat. The cumulative affect of these impacts has resulted in the simplification of the channel network to a single thread channelized system and a dramatic reduction in instream habitat quality.

Basin and reach scale impacts have resulted in a river system that is very confined in some locations and unconstrained in others. The confined sections are typically a result of bridge, riprap, or levee placement that channelizes the river. This typically results in channel incision and degradation of instream habitat. It also results in higher sediment transport capacity meaning that sediment moves through these areas with little if any temporary storage in the channel or floodplain. Unconstrained reaches downstream of constriction points are depositing large amounts of sediments resulting in very active river channels. The river has a greater tendency to migrate and/or avulse through these reaches resulting in greater management issues and concerns.

Located in the lower watershed, the project reach is a depositional environment where sediment from the upper watershed is temporarily stored in the floodplain through natural processes. Altered hydrology because of the dams has reduced peak discharges reducing the transport capacity of the Naches River. This increases the propensity that sediment will be deposited and stored in the floodplain throughout the river including the project reach. This compounds concerns related to reach scale channel aggradation in the Naches River.

APPENDIX I

ALTERNATIVE MANAGEMENT ACTIONS

APPENDIX I

ALTERNATIVE MANAGEMENT ACTIONS

In this section of the report, we describe the types of management actions that could be undertaken throughout the area. Because of differences in fluvial processes, channel patterns, and river/road interactions through the project area, potential management actions differ from one area to another. In addition, the diverse, existing river conditions affect the appropriateness of actions in different locations. Finally, site specific constraints may limit the types, sizes, and extents of management actions that can be undertaken.

Alternatives for managing the Naches River range from discrete actions with the sole purpose of protecting the road prism to reach scale implementation targeting the promotion of natural channel processes and the development of functioning riparian zones with limited environmental deficiencies between the Naches River and US 12.

LEVEL 1 MANAGEMENT ALTERNATIVES

These applications target road protection as the sole project objective. This level of management action is most appropriate for emergency actions where severe risk conditions exist and time is the limiting factor with respect to project implementation. The need for implementing these projects often occurs during non-optimal instream working conditions when the river's discharge is high. Therefore, installation of this type of project must be possible under a range of flow conditions.

Placement of rock revetment

Rock revetments can be placed along the toe of the roadway prism and extended up the prism slope to an elevation near or above the elevation of the 100-year recurrence flow (Figure I-1). Excavation at the toe of the slope is suggested to account for scour that will occur as a result of the rock placement. The primary purpose of a rock revetment is to stabilize a river bank by preventing erosion.

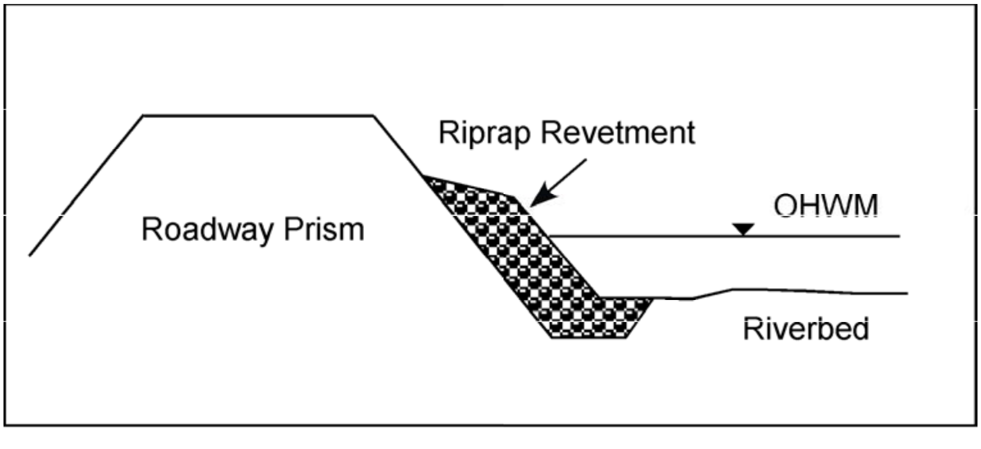

Figure I-1: Typical riprap placement.

Placement of rock groins (aka spurs or barbs)

Rock groins, spurs, and/or barbs have been used in all parts of the world as river training structures and to protect erodable banks (see the Integrated Streambank Protection Guidelines [ISPG] for details). These features are typically elongated obstructions having one end on the bank of the river and the other end projecting into the current (Figure I-2). Barbs and groins can be constructed using rock, but have also been constructed using masonry, concrete, steel, sheet piles, and gabions. The desired effect of a barb or groin is to reduce the current along the riverbank, thereby reducing the erosive capabilities of the river and potentially inducing sedimentation between the structures.

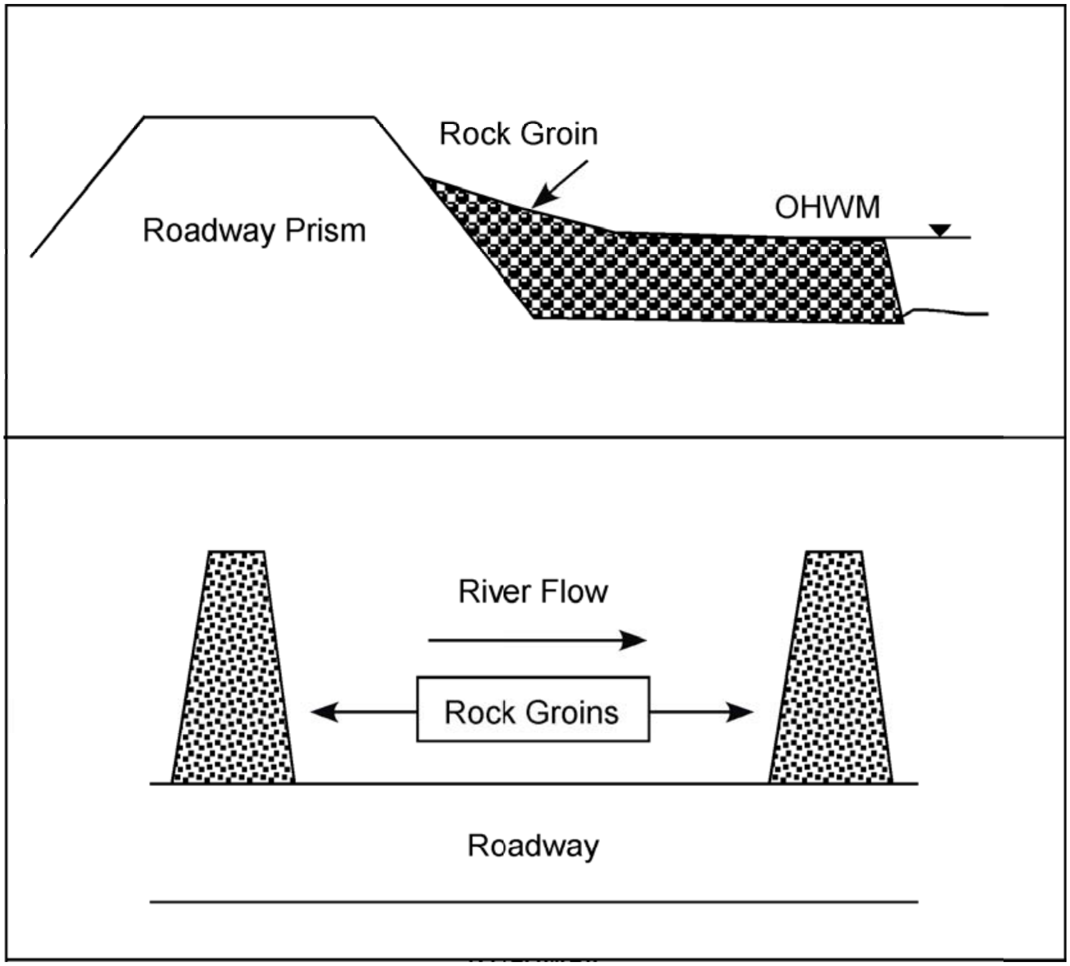

Figure I-2: Typical plan and profile view for rock groins.

LEVEL 2 MANAGEMENT ALTERNATIVES

Level 2 management actions focus on the reclamation of floodplain area adjacent to the roadway and the establishment of a riparian zone between the river and the roadway. These projects are typically large scale in terms of affected area, achieved protection, longterm environmental benefit, and cost. If properly designed and implemented these projects can be cost effective in that they address site conditions comprehensively and can require little maintenance over time. The overall concept is to move the river away from the road and maintain it at some distance from the roadway. The initial step is isolating the river from the roadway by placing a rock revetment or large woody debris (LWD) cribwall within the active channel at some distance from the roadway. Fill material that will facilitate the growth of riparian trees and shrubs is brought in to fill void space created by the placement of the revetment/cribwall and help establish riparian growth. These actions require a comprehensive riparian forestation and maintenance plan.

Isolating the river using a rock revetment

The placement of a rock revetment within the active river channel could be done in various configurations. One option is to construct a rock revetment in the active channel at some pre-determined distance from the roadway. Fill material with some soil composition would be imported into the lee of the revetment and would be planted with appropriate riparian trees and shrubs. Conceptual plan and profile views are shown in Figure I-3 below.

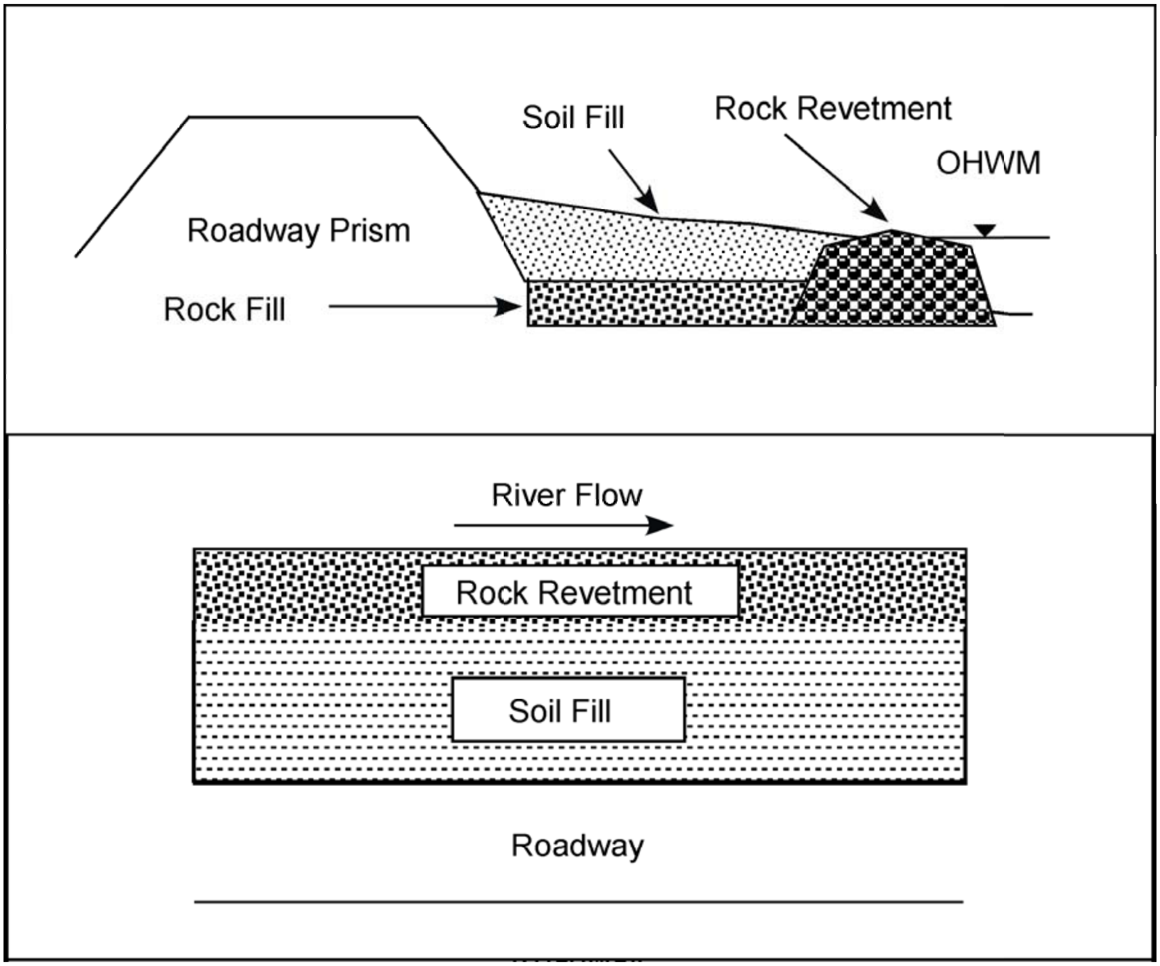

Figure I-3: Typical plan and profile view for floodplain reclamation using a rock revetment to isolate the river.

The soil fill is necessary to establish riparian growth in the area between the river and US 12. Without proper soil materials, the success of a riparian planting plan and the longterm growth and natural recruitment of native species may be compromised.

Another potential configuration would be the incorporation of groins into the design. This may provide increased stability during extreme flow events if flood elevations rise above the revetment and flow across the soil fill area. A typical plan view with groins incorporated into the design is displayed below in Figure I-4.

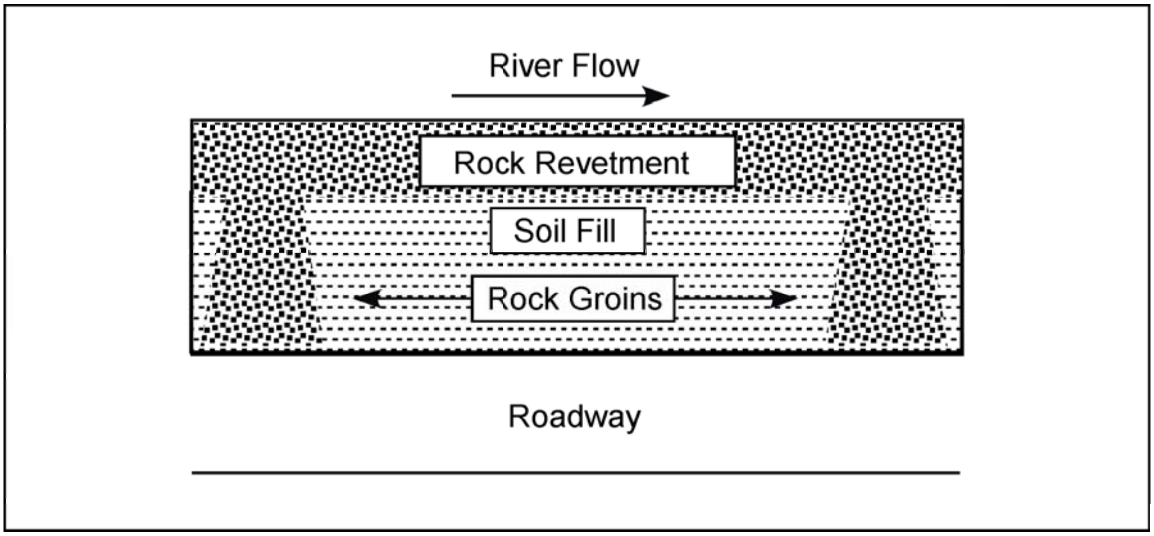

Figure I-4: Typical plan view of floodplain reclamation incorporating rock groins.

The installation of either of these rock configurations will likely require mitigation. Mitigation actions would target improving instream habitat conditions and/or enhancing riparian areas.

Isolating the river using a LWD revetment or cribwall

Isolating the river from the roadway can also be accomplished using a revetment or cribwall constructed primarily with large woody debris. An example of this type of application is shown in Figure I-5.

Figure I-5: LWD revetment constructed as part of the South Fork Nooksack, Larson's Bridge Project, approximately RM 20.

This structure was constructed as part of the South Fork Nooksack, Larson's Bridge Engineered Log Jam Project (GeoEngineers 2001). The objective of this structure was to isolate the river from the landslide to prevent toe erosion and provide an area for the slide to fail into and establish an angle of repose. Halting this failure will also protect a road located just off the top of the bluff. This type of structure is constructed by interlocking large trees together to form a stable configuration. The result of this approach is a more natural looking structure that creates instream habitat while providing protection of human infrastructure. Conceptual profile view is shown in Figure I-6.

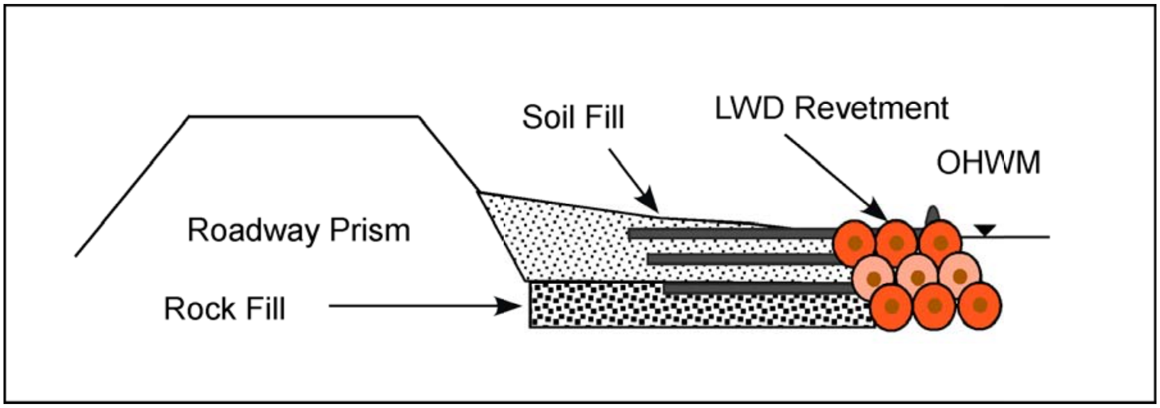

Figure I-6: Typical profile view of LWD revetment isolating the river from the roadway.

This approach also lends itself to the establishment and growth of a healthy riparian zone. Additional benefits are that these structures will enhance instream habitat conditions and will likely not require additional mitigation.

LEVEL 3 MANAGEMENT ALTERNATIVES

These management actions target placing or removing structural components in geomorphically significant locations through the project reach. These placements or removals would encourage natural geomorphic processes to alter river dynamics resulting in more desirable conditions. These actions consider the treatment of river reach dynamics as opposed to just the problematic sites and has been used in several reach scale management projects to date.

Placement of Engineered Log Jams

Engineered Log Jams (ELJs) are instream hydraulic structures comprised primarily with LWD that can be used to solve common river engineering problems involving grade control, flow manipulation, and channel training (Figure I-7).

Figure I-7: ELJ constructed as part of the North Fork Stillaguamish, ELJ project.

The design premise of ELJs is to emulate naturally occurring structures and processes found in fluvial environments. Wood debris accumulations have been found to be the primary feature affecting geomorphic change in natural systems. A properly designed and constructed ELJ can perform as a revetment, barb, or groin, with the benefit of introducing significantly more habitat complexity to the channel while blending into the natural environment. ELJs have been used to redirect flow approaching bridges and provide reach scale bank protection protecting roads, hillslopes, and providing avulsion prevention. A typical for an apex ELJ is displayed in Figure I-8.

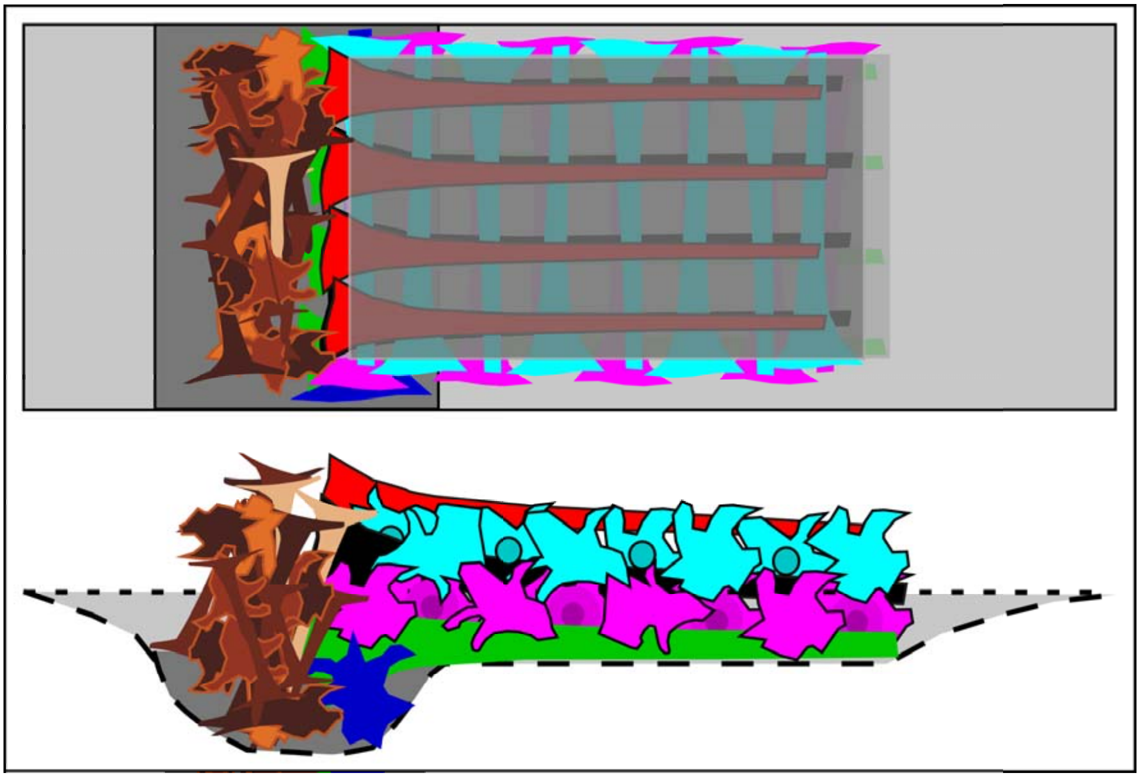

Figure I-8: Typical plan and profile view of an ELJ.

Removal of levee and/or riprap

Perhaps the initial consideration in addressing channelization and incision is the removal of the mechanisms that are creating these impacts. In the project reach, placed rock and levee impoundments have channelized flow and affected the sediment dynamics of the river. Removal of the installations, where possible, will reduce the altered dynamics resulting in more natural conditions. This will help reduce the concentrated erosional and depositional environments seen today and distribute temporary sediment storage through greater extents of the project area. Specific locations of potential levee removals and/or modification are discussed later in this document.

LEVEL 4 MANAGEMENT ALTERNATIVES

These management actions target the protection of desirable instream and floodplain features, enhancement of riparian conditions, and the creation and/or maintenance of aquatic habitat. These actions seek to protect or enhance existing conditions as a method of preventing future degradation. These actions can also be used as off-site mitigation should the need arise.

Placement of Engineered Log Jams

As discussed, Engineered Log Jams can be placed such that they provide human objectives such as flow deflection and bank protection. Engineered Log Jams also create pool habitat with cover and complex hydraulic conditions desirable for anadromous and stream fishes. Engineered

Log Jams have been used primarily for the creation of fish habitat for pool creation and for the diversification of channel networks by splitting flows and creating secondary channels Figure I-9.

Figure I-9: ELJ constructed as part of the South Fork Nooksack, Larson's Bridge Project.

Engineered Log Jams have also been constructed as mitigation for the placement of rock revetments in other river systems.

Placement of wood debris

Placement of wood debris differs from the installation of Engineered Log Jams. This wood is placed in floodplain and/or overbank areas where it interacts with the river only during high flows, under the existing site conditions. These placements can be made to reduce the likelihood of local erosion, protect specific areas under high flow conditions, or to induce desired conditions as the river migrates into the placement area.

Single log placements

Placement of single logs is done on bars or in riparian areas where the recruitment, establishment, and growth of riparian vegetation is desired. These logs are placed in areas where overbank flow travels during high flow events. The objective of the logs is to disperse flow such that concentrated flow is broken up and the likelihood of scour is reduced. Example placements are shown in Figure I-10.

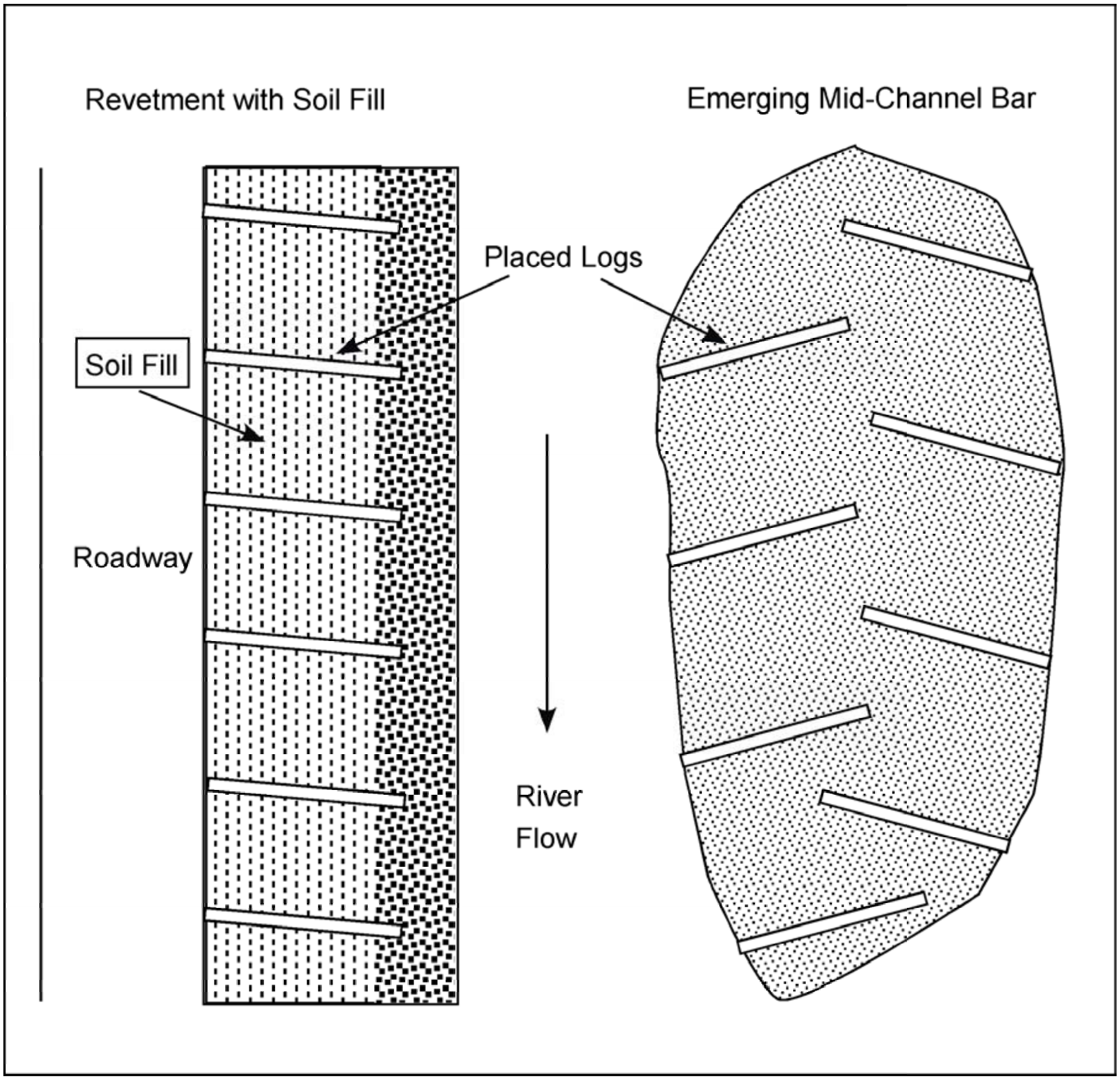

Figure I-10: Example placements of single logs on bar formations and floodplain areas.

Log Clusters

Logs can also be placed in clusters in specific locations (Figure I-11). The objective of these clusters can be to disperse energy or deflect flow to more desirable locations within the floodplain. Log clusters can also be placed at the head of emerging bars to deflect flow around the bar providing scour protection and enhancing riparian establishment and development. This can be done in combination with single log placements. In addition, log clusters can be placed in bar or floodplain areas where channel migration into the area is likely. In this application, the objective can be to protect a specific area from channel avulsion or to protect or create an immature riparian unit allowing it to mature into a mid-channel forested island. The size and distribution of these log clusters is dependent on site specific conditions and objectives.

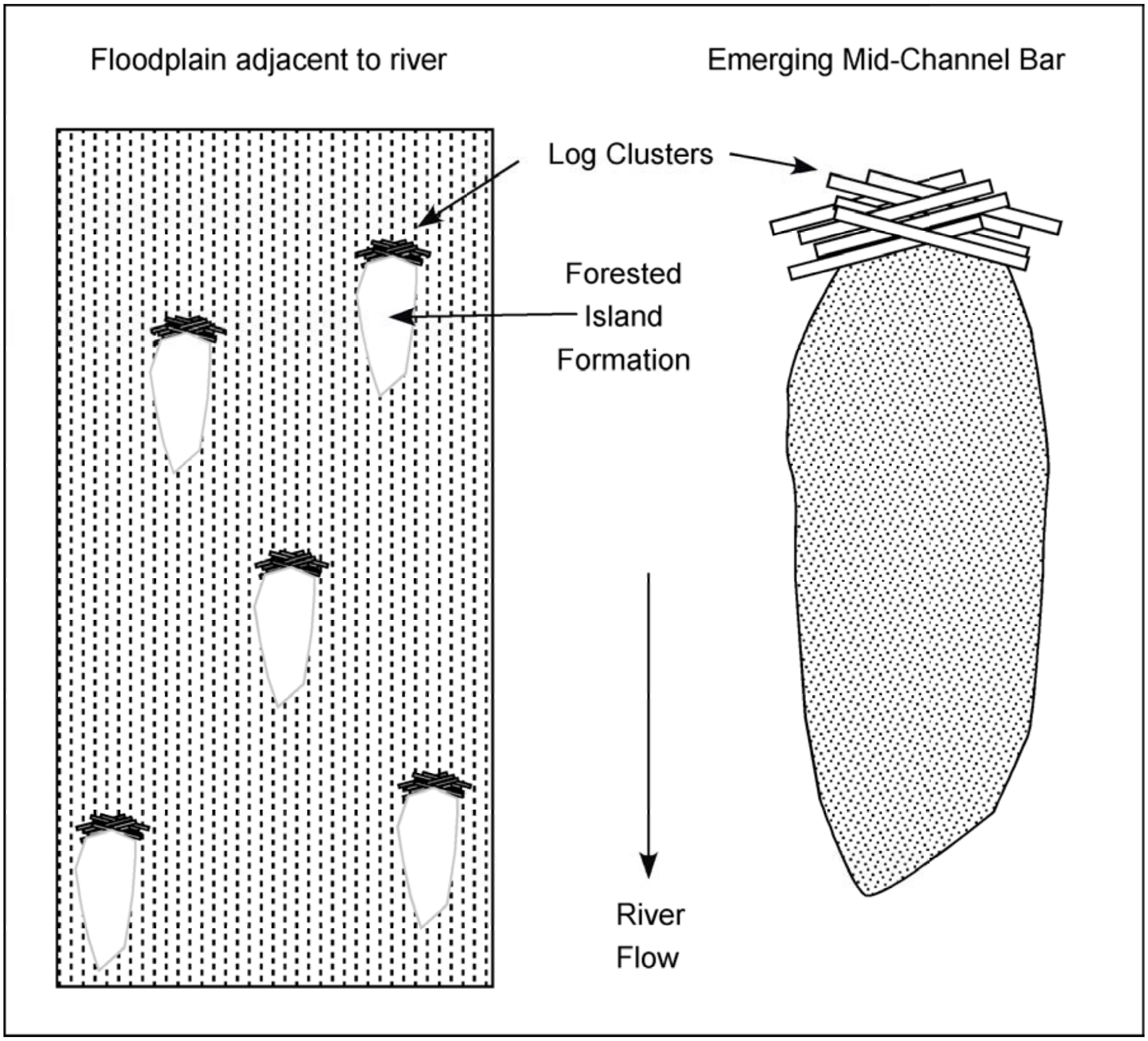

Figure I-11: Typical placement of log clusters in emerging bar and floodplain locations.

Planting of riparian areas

Riparian plantings typically target promoting the stability of the planted unit, increasing the density of riparian vegetation, or enhancing the species diversity of a stand by establishing trees, typically conifers, for which seed sources have been lost. Plantings can be part of passive protection efforts or incorporated into other types of management actions to supplement those activities. Riparian planting activities can also be conducted either on or offsite as mitigation for other management actions or construction disturbances. Appropriate species for planting at specific locations is dependent upon existing riparian conditions, elevation relative to flood elevations, and desired longterm riparian species distribution.

APPENDIX J

REPORT LIMITATIONS AND GUIDELINES FOR USE

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REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOTECHNICAL, GEOLOGIC, AND GEOMORPHIC SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for the exclusive use of the Washington State Department of Transportation and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

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This report has been prepared for the Washington State Department of Transportation. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those:

- additional information not available at the time of the report;
- additional analyses not available at the time of this report;
- large-scale changes in upstream landuse or management activities;

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[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

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This geotechnical, geologic, or geomorphic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or ground water fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

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Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering, geologic, or geomorphic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering, geology, or geomorphology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory “limitations” provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these “Report Limitations and Guidelines for Use” apply to your project or site.

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The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical, geologic, or geomorphic study and vice versa. For that reason, a geotechnical engineering, geologic, or geomorphic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.