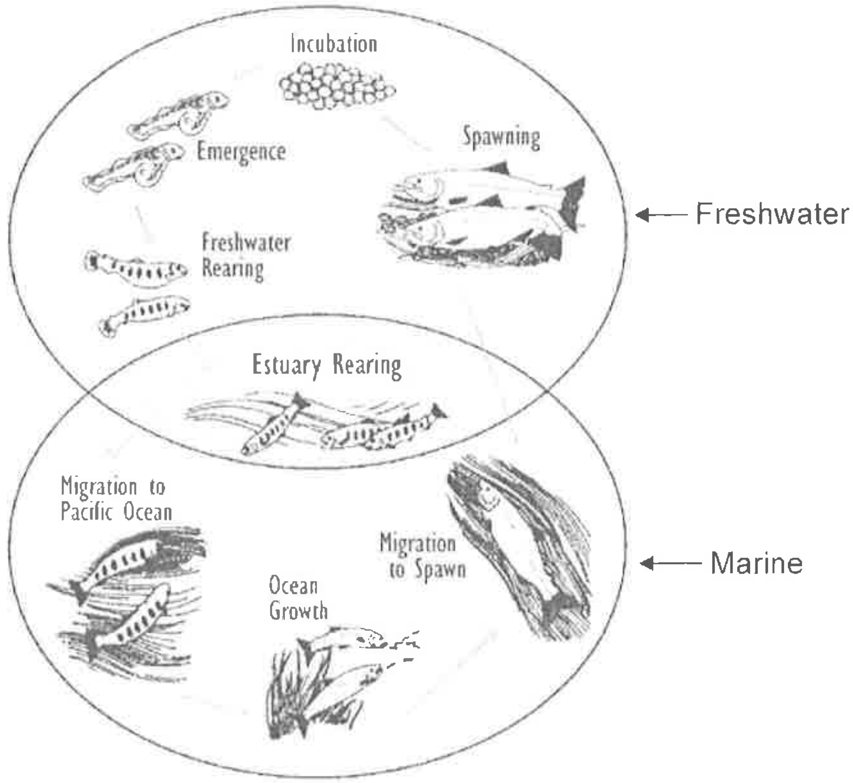
WASHINGTON STATE AQUATIC HABITAT GUIDELINES PROGRAM

Stream Habitat Restoration Guidelines 2012

anadromous salmonids depends upon their ability to occupy and move among freshwater, nearshore and open ocean habitats (Fresh 2006).

FIGURE 2.1 Anadromous Fish Life Stages



Graphic courtesy of Washington Department of Fish and Wildlife

Salmonids have evolved with diverse life history trajectories allowing them to exploit interannual variation in conditions. For example, within the same river system Chinook salmon juveniles may migrate directly to sea as fry, migrate to the delta and rear for months before moving to sea, migrate to the nearshore but move into subestuaries for rearing, or remain in the river system for months before migration to sea (Fresh 2006). Therefore, it is important to retain healthy habitat in a variety of habitats to allow exploitation of a variety of different life history trajectories and spatial structure (McElhany et al. 2000). Following is an overview of salmonid life stages.

Table 2.1: Planning tools to manage development impacts on salmonid habitat

Development Action	Potential Impact on Salmonid Habitat Function	Potential Planning Tool to Manage Development Impacts
River channel clearing and channelization (stream bank alterations)	Water quality, flow regime, habitat structure, access	Channel Migration Zone protection (3.2.9), riparian buffers and vegetation retention (3.2.3),[9] floodplain protection (3.2.8), large woody debris recruitment (3.2.6), in-stream work standards (3.2.7), clearing and grading standards (3.3.4)
Loss of riparian vegetation	Water quality, flow regime, habitat structure, food source	Riparian buffers and vegetation retention (3.2.3), building setbacks (3.3.5), stormwater management (3.2.2), LID practices (3.2.2), clearing and grading standards (3.3.4), LWD recruitment standards (3.2.6), habitat restoration projects (3.2.1), incentives to protect habitat (3.3.10)
Loss of forested areas	Water quality, flow regime, access, habitat structure	Forest land conversion regulations (3.3.8), riparian buffers and riparian vegetation retention on all streams (3.2.3), LWD recruitment standards (3.2.6), incentives to protect habitat (3.3.10), zoning regulations (3.3.2)
Loss of farmland	Flow regime, access, habitat structure	Zoning regulations (3.3.2), incentive programs to retain working farmland that follow best management practices (e.g., purchase or transfer of development rights, voluntary restoration programs) (3.3.7; 3.3.10).

[9] Restoration projects that provide a net benefit to habitat functions are allowed in buffers. Buffers are intended to prohibit development and vegetation clearing in the riparian buffer.

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Table 2.1: Planning tools continued

Development Action	Potential Impact on Salmonid Habitat Function	Potential Planning Tool to Manage Development Impacts
Loss of wetlands	Water quality, flow regime, habitat structure, food source	Wetland buffers and development standards (e.g., no-fill) (3.2.5), building setbacks (3.3.5), clearing and grading standards (3.3.4), incentives to protect habitat (3.3.10).
Loss of estuarine and nearshore areas	Water quality, habitat structure, food source, access	Shoreline development standards/ riparian buffers and vegetation retention (3.2.3; 3.2.4), building setbacks (3.3.5), floodplain protection (3.2.8), incentives to protect habitat (3.3.10).
Bulkhead and overwater structures	Water quality, flow regime, habitat structure, food source	Shoreline development standards/ riparian buffers and vegetation retention (3.2.3; 3.2.4), building setbacks (3.3.5), floodplain protection (3.2.8).
Upland clearing and grading	Water quality, flow regime, habitat structure, food source, access	Zoning regulations (3.3.2), Channel Migration Zone protection (3.2.9), Landslide Hazard Area protection (3.2.10), riparian buffers and vegetation retention (3.2.3), floodplain protection (3.2.8), clearing and grading standards (3.3.4).
Fish passage barriers	Flow regime, habitat structure, access	Road standards (3.3.6), non-commercial forest practices (3.3.8).
Water allocations/ stormwater runoff	Water quality, flow regime	Stormwater management (3.2.2), LID practices (3.2.2), water quality standards (3.2.11).
Industrial effluent	Water quality	Zoning regulations (3.3.2), water quality standards (3.2.11).

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Figure 16.

(a) Channel-spanning log jam

(b) Log jam accumulated along the bank

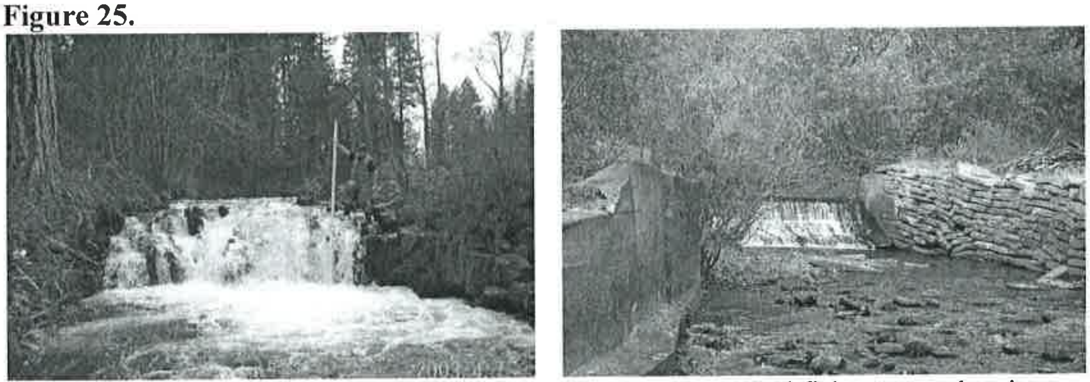
(c) The key piece in this jam is a large tree that toppled into the stream while remaining rooted in the bank. Wood accumulated along the outside of a bend in a high energy system. Spanning pieces have minimal interaction with the flow.

(d) A log jam that has formed on a low bar outside of the low flow channel. This jam interacts with moderate and higher levels of flow. Note the plume of sand that has accumulated in the 'lee' downstream of the Jam. Source: Paul Bakke

Irrespective of channel width, trees falling directly into the channel from the banks (as contrasted with those delivered from the uplands by mass-wasting) often are anchored to the bank by roots. Depending on the orientation of the trunk, the tree may provide protection to the bank by reducing flow velocities. Conversely, it may cause bank erosion by directing flow toward the bank or by causing an eddy. Although large wood has the potential to increase local erosion, on the larger scale it reduces erosion by dissipating energy. In a survey of 41 channels in north-western Washington and Alaska, Montgomery and Buffington (1999)[39] found significant fining of streambed sediments associated with the presence of large wood and other roughness features (indicating increased energy dissipation). The species of trees available to the stream has a strong influence on the interactions between wood and the channel. Tree size is an obvious factor influenced by species: the larger the wood, the greater its ability to physically affect the stream. Buoyancy, which differs among tree species, also relates to the behavior of large wood when it enters the stream. Low-density wood, such as spruce or western red cedar is more readily floated than higher-density wood such as Douglas fir.

combination of reduced root strength and soil saturation may trigger landsliding and debris torrents capable of scouring and damming channels. It should be noted that extremely infrequent and severe events might affect even relatively large streams, such as in 1980, when the Toutle River was overwhelmed by mud and debris flows triggered by the eruption of Mt St. Helens. Connectivity within the system is key to re-colonizing these sites following severe disturbance.[47] When habitat connectivity is lost, migratory species may be excluded, and disturbance can lead to local extinction of resident species (see Figure 25).

Figure 25.



(a) Natural fish passage barrier | (b) Human-created fish passage barrier

Lateral Connectivity

The lateral dimension of the stream corridor extends across the channel and floodplain. Riparian/ floodplain habitats may consist of side channels, off-channel ponds and wetlands, perennial or intermittent streams and springs and periodically flooded grasslands and forests.[33] These riparian/floodplain habitats offer feeding, reproduction, and refuge habitat for invertebrates, fish, amphibians, reptiles, birds, and mammals. Flooding provides periodic or episodic surface connection between the various floodplain features and the active channel, allowing the exchange of organisms and materials (e.g., wood, sediment, solutes). Figure 26 illustrates the simplification caused by diking.

Table 3.1. Typical response time, duration, variability in success, and probability of success of common restoration techniques. Adapted from Beechie et al.[15] as modified from Roni et al.[7]

Restoration type[a]	Specific Action	Years to achieve response	Longevity of action (years)	Variability of success among projects	Probability of success
Reconnect Habitats	Culverts	1-5	10-50+	Low	High
	Off channel	1-5	10-50+	Low	High
	Estuarine	5-20	10-50+	Moderate	Moderate to High
	Instream Flows	1-5	10-50+	Low	High
Roads and land use	Road removal	5-20	Decades to centuries	Low	High
	Road alteration	5-20	Decades to centuries	Moderate	Moderate to high
	Change in land use	10+	Decades to centuries	Unknown	Unknown
Riparian restoration	Fencing	5-20	10-50+	Low	Moderate to high
	Riparian replanting	5-20	10-50+	Low	Moderate to high
	Rest-rotation or grazing strategy	5-20	10-50+	Moderate	Moderate
	Conifer conversion	10-100	Centuries	High	Low to moderate
Instream habitat restoration	Artificial log structures	1-5	5-20	High	Low to High[b]
	Natural LWD placement	1-5	5-20	High	Low to High[b]
	Artificial log jams	1-5	10-50+	Moderate	Low to High [b]
	Boulder placement	1-5	5-20	Moderate	Low to High [b]
	Gabions	1-5	10	Moderate	Low to High [b]
Nutrient enrichment	Carcass placement	1-5	Unknown	Low	Moderate to high
	Stream fertilization	1-5	Unknown	Moderate	Moderate to high
Habitat creation	Off channel	1-5	10-50+	High	Moderate
	Estuarine	5-10	10-50+	High	Low
	Instream	See various instream restoration techniques above			

Where sustained long-term funding is available, assessments may be incremental, with efforts focusing on new sub-basins within a watershed, or issues and effects not previously assessed. However, it is important to integrate incremental assessments with previous information to get a better handle on the cumulative effects and cause and effect relationships between physical, chemical, and biotic processes operating at a watershed scale.

The following considerations are recommended when determining the necessary scope and scale of assessment for restoration and project planning:

<u>Restoration Planning</u>:

- What are your assessment goals? Is there a particular issue you are trying to address (e.g., elevated nitrogen and low dissolved oxygen concentrations in the nearshore environment) or is your objective to identify and prioritize issues and restoration/management initiatives in the watershed? Is your objective restricted to project-specific reconnaissance?
-

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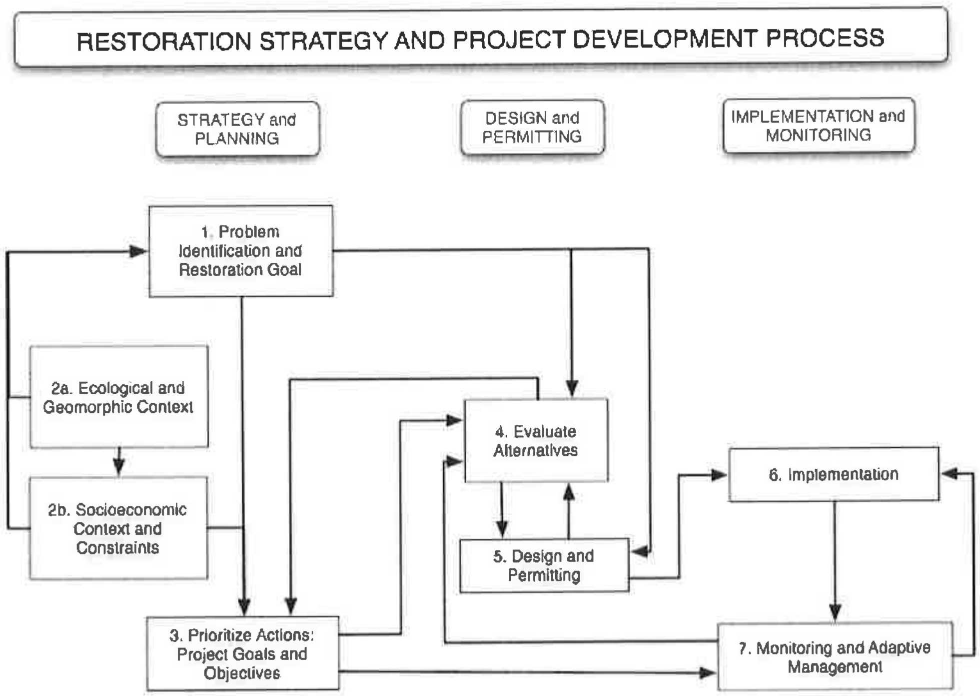
Figure 1. Restoration strategy and project development process. The outcomes of Strategy and Planning are prioritized and coordinated restoration actions and projects with defined goals and measurable objectives. (Adapted from RiverRAT).



The outcome of the restoration planning process will typically consist of a general restoration goal and a strategy, or plan of action that includes a prioritized set of specific restoration actions and projects. For each specific action or project identified, project-specific goals and objectives are necessary to guide design, implementation, and monitoring of individual projects. Individual restoration projects are, therefore, components of a restoration strategy that prioritizes actions and projects within a watershed context. The restoration strategy development and planning process (Steps 1-3) is described in this chapter; design development, permitting, and approaches to restoration actions (Steps 4-6) are described in Chapter 5; monitoring and adaptive management (Step 7) is described in the *Monitoring* Appendix.

4.1 Problem Identification and the Restoration Goal

The call for stream restoration is often initiated when there is a compelling reason to address an observed problem, such as declining recruitment of native fish or deteriorating water quality. Articulating a problem is a subjective exercise. Lack of habitat, for example, is not inherently a problem unless you are a fish; flooding is not a problem unless human property is affected. From this subjective perspective, 'problems' can be characterized as limited or exacerbated conditions that affect the interests of native aquatic species or humans. Common problems that lead to a call for restoration include degradation of water quality, declining population, recruitment, or range of native species, and property loss or damage.

The *problem* should serve as the basis for defining restoration goals; the *root causes* of the problem should inform the selection of restoration strategies and actions. Differentiation of problems (conditions) from their root causes (processes) is critical to developing appropriate restoration strategies

Table 1. Example root causes of habitat loss or degradation at varying scales. Assessed or observed habitat loss or degradation can usually be attributed to disruption or constraint of processes that create and maintain habitat. Impacted processes can often be attributed to a root cause, which may occur at a site, reach or watershed scale. This table lists common root causes of impacts to the processes that in turn result in loss or degradation of stream habitat. Ideally, restoration actions are directed to addressing root causes to prevent additional or recurring habitat impact.

SCALE of IMPACT	IMPACT/CAUSE	PROCESS/VARIABLE AFFECTED
Watershed	urbanization	hydrology and sediment supply
	climate change	hydrology
	forestry and roads	hydrology and sediment supply
	agricultural conversion	hydrology and sediment supply
	dams and diversions	hydrology and sediment supply
Reach	channelization	slope and sediment transport
	levees	hydraulics and floodplain inundation
	snag removal	hydraulics, sediment transport and storage
	channel training and armoring	bank stability, hydraulics, sediment transport and storage
	riparian vegetation management/removal	bank stability, hydraulics, sediment transport, supply and storage
	infrastructure encroachment	bank stability, hydraulics, sediment transport and storage
	grazing and trampling	bank stability
Site	bank armoring	bank stability, hydraulics, sediment transport and storage
	Infrastructure, stream crossings, and building encroachment	bank stability, hydraulics, sediment transport and storage
	snag removal	hydraulics

Watershed-scale causes often impact independent variables of hydrologic regime and sediment regime. Root causes at this scale can profoundly affect stream habitat conditions throughout a watershed by upsetting the equilibrium between hydrologic and sediment variables and boundary conditions, resulting in channel instability and associated habitat degradation. Where restoration strategies cannot address causes at this scale, reach-scale strategies must account for changes in the independent variables that govern stream processes and associated habitat availability and character. Reach-scale root causes often affect boundary conditions (e.g. bank stability, substrate character, slope) and in-channel variables (e.g. hydraulics and sediment transport rates). One of the most common and problematic reach-scale impacts is the confining of a channel migration zone (e.g. levees) or a channel's ability to adjust (e.g. streambank protection), effectively constraining processes that create and sustain habitat through channel migration and associated riparian and in-stream habitat succession. Impacts to boundary conditions can upset equilibrium conditions and set in motion a series of channel adjustments and associated habitat degradation that may extend up- or down-stream. Site-scale causes are similar to reach-scale causes, but are limited in extent to a few habitat units.

4.1.1 Restoration Goals and Objectives

The goal of restoration is to remedy observed problems, ideally by addressing their root causes. Ideally, restoration goal statements should articulate desired outcomes and who or what benefits from those outcomes. Articulating a goal in the context of the subject of the identified problem can greatly facilitate development of restoration strategies. Consider the following two similar goal statements developed to address the problem of a declining fishery where habitat has been determined as a dominant limiting factor:

1. Restore the extent and diversity of aquatic habitat to pre-disturbance conditions.

Besides restoring connectivity, consideration is given to the condition and quantity of the disconnected habitat. Priority should be given to restoration of connections to abundant, high-quality, and sustainable habitat. Where disconnected habitat is degraded or only provides very limited additional capacity, then restoring connectivity may be of little value unless habitat restoration or restoration of habitat processes is integrated in the restoration strategy.

Table 2, while not exhaustive, suggests techniques that may be appropriate for restoring connectivity given common physical barriers and constraints. Additionally, the *Fish Passage Restoration Technique* and the *Design of Road Culverts for Fish Passage Guidelines*[21] provide detailed information and considerations for channel and structure design to facilitate fish passage.

Table 2. Selection of techniques to restore connectivity of habitats, based on causes of impacts. Causes and solutions presented are not exhaustive, but provide examples of techniques to consider in addressing causes at varying scales. Causes listed are not necessarily root causes. For example, channel incision* may impact habitat and connectivity, but typically has a root cause of either channelization or watershed-scale change to sediment or hydrologic regimes.

Impact/Cause*	Scale of Impact	Connectivity Dimension	Solution	Restoration Technique
Diversions or other weirs	Site	Longitudinal	Removal or reconfiguration of structure	Instream structures; Channel modification, Fish passage, Dedicating Land and Water
Culverts	Site	Longitudinal	Removal or reconfiguration of structure	Instream structures; Channel modification; Channel profile, Fish passage
Dams	Site; reach	Longitudinal	Removal or reconfiguration of structure; install fish ladder	Instream structures; Channel modification, Fish passage
Tide gates	Site	Longitudinal, Lateral	Removal or reconfiguration of structure	Fish passage
Levees	Reach	Longitudinal, Lateral	Levee removal, breach levees	Floodplain and Channel Migration Zone Restoration; Floodplain fencing, Riparian restoration; Dedicating land
Floodplain fill	Reach	Longitudinal, Lateral	Remove fill, Riparian revegetation	Channel modification; Side channels; Riparian restoration; Dedicating land
Channelization	Reach	Longitudinal, Lateral, Vertical	Reconfigure the channel; raise channel bed	Channel modification; Instream structures; Channel profile; Dedicating land
Channel incision*	Reach	Longitudinal, Lateral, Vertical	Reconfigure the channel; raise channel bed	Channel modification; Instream structures; Channel profile;

				Dedicating land
Bank stabilization	Reach	Lateral, Vertical	Remove stabilization features; reconfigure channel and banks, riparian revegetation	See Integrated Streambank Protection Guidelines; Channel modification; Riparian restoration; Dedicating land
Hydrologic or Sediment regime	Watershed	Longitudinal, Lateral, Vertical	Restore regime, reconfigure channel, stabilize channel	Channel modification; Instream structures; Channel profile; Dedicating land

4.6 Restoring Habitat-Forming Processes

The third priority for habitat restoration strategies, following protection and connection of existing habitats, is the restoration of habitat-forming processes. Habitat is an outcome of a hierarchical set of inputs, processes, and variables – sustainable habitat restoration therefore requires restoration of the inputs, processes and variables that create and maintain habitat [1]. Habitat consists of physical, energy, and water quality elements. While the following sections emphasize strategies to restore physical processes, strategies for restoration of energy and water quality processes are also discussed. Restoration of degraded habitat requires that the root cause of degradation be identified and addressed at appropriate scales if the treatment is to provide long-term, sustainable results[6,7].

At the watershed scale, processes are governed primarily by the sediment regime and the hydrologic regime (Chapter 2, Hydrology and Sediment appendices), consequently, restoration strategies may focus on restoring or modifying sediment inputs and the hydrologic regime. In instances where land-use and development patterns at the watershed scale preclude significant reversal of impacts to the sediment and hydrologic regime, such as in the case of wide-scale agricultural conversion of historic forestland or urbanization, it may be practically impossible to restore the character of the regimes that drove channel processes. In this case, alternatives are to adapt the channel, or allow the channel to adapt, to new sediment and hydrologic regime, or alternatively to adopt a strategy of "managed inputs". Restoring hydrologic regime, sediment regime, and managed inputs are described in following sections.

Two common expressions of impacted sediment and hydrologic regimes are incised channels and aggrading channels (refer to Chapter 2, the Geomorphology Appendix, and to RiverRAT Section 2-6.3, Channel Incision and Evolution). Determining an appropriate strategy to address incised or aggrading channels will require detailed watershed-scale assessment, supplemented with reach-scale sediment transport analyses to establish cause-and-effect relationships. While incision and aggradation are generally indicative of fundamental changes in watershed inputs, these changes may result from natural changes in watershed condition (such as due to volcanic eruption, major landslide, loss of glaciers in headwaters, or extensive fire alteration of vegetation) or may be the result of direct or indirect human impacts that affect hydrologic or sediment processes. Incised and aggrading reaches may warrant reach-scale restoration strategies in addition to restoration of hydrologic and sediment inputs, or where restoration of these inputs is impractical. Strategies for addressing incised and aggrading channels are also described in following sections.

At the reach scale, habitat-forming processes are governed by boundary conditions – the soils, vegetation, floodplain, and geological conditions within which dynamic channel processes and

Table 3. Examples of strategies and techniques to address general sediment-supply or transport problems and causes			
Problem	**Causes**	**Strategy**	**Relevant techniques**
Watershed-scale problems, causes and strategies			
Excess sediment	Forestry, agricultural practices	Upland forestry or agricultural BMPs to stabilize soils and reduce runoff	Riparian Restoration, Dedicating land.
	Systemic instability	Sediment detention basin, No action	Sediment detention basin; Dedicating land
Decreased sediment; increased transport	Urbanization; Dams	Channel stabilization to check incision; channel modification to balance transport with supply; Dam removal; sediment augmentation	Instream structures; Large wood; Channel modification; Spawning gravel; Beaver reintroduction; Dedicating land
Reach-scale problems, causes, and strategies			
Excess sediment	Riparian vegetation impacts	Revegetation; land-use BMPs	Riparian restoration; Dedicating land
	Channel incision	Stabilize channel and banks; Reconfigure channel	Riparian restoration; Channel modification; Instream structures; Dedicating land and water
Decreased sediment; increased transport	Bank armoring; Channelization	Remove armoring and channel constraints; Reconfigure channel and banks; restore channel roughness	Riparian restoration; Channel modification; Instream structures; Beaver reintroduction; Dedicating land

4.7 Flow Regime

The flow regime refers to the characteristic seasonal and inter-annual variation of volume and timing of stream flow (see also Chapter 2). Stream flow provides the energy that drives stream ecosystem processes, including the creation and maintenance of habitat and provides the energy to transport and distribute water, sediment, organic material, nutrients, and thermal energy within the stream corridor[22]. Together with sediment supply, the flow regime is the dominant watershed-scale factor governing the formation of stream channels and associated habitat. Flow regime is commonly characterized using flow statistics including magnitude, frequency, timing, and duration of flows (refer to the *Hydrology* Appendix for further description and methods for analyzing flow regime). Despite its importance as a dominant variable that influences habitat-forming processes, flow regime restoration is one of the most neglected aspects of stream restoration[5].

Besides in-channel flow, the flow regime influences the water level of nearby groundwater and surface water bodies (such as wetlands, lakes, and ponds) and dictates the frequency, extent, and duration of floodplain inundation. These, in turn, influence the distribution and composition of riparian vegetation and wildlife, and the exchange of nutrients, water, sediment, vegetation, contaminants, organisms, and organic material between the floodplain and the stream. High flows transport sediment, control vegetation encroachment into the active channel, and influence the structural stability of streambanks. They also contribute to the disturbance regime of a stream serving as a mechanism for creating and maintaining diverse aquatic floodplain, and riparian habitat[20 23].

Flow also determines the amount of available aquatic habitat for a given point in the channel over time. At its simplest, aquatic habitat is living space or volume; habitat volume generally increases with flow volume. However, the quality of living space (or spawning or incubation space) is determined by other flow-related factors, such as depth, velocity, cover, bottom material (substrate), and water quality[20]. Despite the variability of streamflow during the course of a year, the seasonal timing of high and low

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Where addressing root causes is impossible or impractical, or where channels have been drastically de-stabilized due to flow regime change, reach-scale channel stabilization or reconfiguration will likely be necessary to check any further degradation and to create a channel type that is more appropriate for the 'new' flow regime. Similarly, where changes to flow conditions are primarily the result of reach-scale changes to channel or floodplain condition, reach-scale strategies may be appropriate. Because the variables influencing flow regime and channel response to changes in regime are so complex, it is impractical to outline restoration strategies for every conceivable impact. However, where a clear relationship between impacts to flow regime and channel or habitat effects can be determined through watershed and hydrologic assessment, restoration strategies can be selected. Examples are provided in Table 4.

Table 4. Examples of strategies and techniques to address general flow regime problems and causes

Problem	Causes	Strategy	Relevant techniques
Watershed-scale problems, causes and strategies			
Increased flow and stream energy	Development, urbanization	Stormwater and runoff management; Channel stabilization and enhancement	Instream structures; Large wood; Bank protection
	Land conversion	Land use BMPs, Riparian buffers; Channel stabilization and enhancement	Instream structures; Large wood; Bank protection; Dedicating land
Increased flow variability	Development; urbanization	Stormwater and runoff management; Channel stabilization and enhancement	Instream structures; Large wood; Bank protection; Dedicating land and water
Depleted low flow	Diversions, dams	Flow regulation management; Dam or diversion removal or retrofit	Channel modification
	Reduced recharge from beaver removal, other floodplain modification	Beaver restoration; Levee removal; Floodplain restoration	Channel modification; Levee modification; Beaver reintroduction; Riparian restoration; Dedicating land and water
	Aggradation	See Table 7 - Strategies to address aggradation	See Table 7
Decreased high flows (effective discharge)	Dams	Dam removal, retrofit, or flow management	Channel modification, Dedicating land and water
Reach-scale problems, causes and strategies			
Increased flow and stream energy	Levees, confined or modified channel	Levee removal or breach; Channel restoration; Floodplain restoration	Channel modification; Floodplain and CMZ Restoration; Riparian restoration; Dedicating land

4.7.1 Managed Inputs – Gravel, Wood, and Nutrients

Instances may exist where inputs to processes that are essential to ecosystem health have been disrupted or disconnected and cannot recover to pre-disturbance levels within reasonable timeframes. Where inputs to processes may require years to decades to be restored, these processes may be artificially augmented through a deliberate, managed input of material to the stream.

Commonly applied strategies include supplemental input of sediment, wood, or nutrients to the stream. Instream flow requirements (e.g. spring floods or minimum instream flows) can also be considered as deliberate managed inputs, but are not explicitly discussed in this guideline. In these guidelines, supplementation is defined as the input of materials to a channel without specialized or secured placement.

Material supplementation in alluvial streams generally relies on flow events to distribute materials through the channel and floodplain; in colluvium dominated streams material is contributed and distributed primarily from mass wasting events. This strategy, therefore, requires careful consideration of the stream type and character and impacts to the flow regime and any changes in channel and floodplain conditions, including the timing and probability of flow events necessary to distribute materials. This strategy, therefore, requires careful consideration of the character and impacts to the flow regime and any changes in channel and floodplain conditions, including the timing and probability of flow events necessary to distribute materials. It may take weeks, months, or years before benefits are realized, depending on the magnitude and timing of flows. As hydrology is difficult to predict, the timing, extent, and longevity of material distribution is also difficult to predict. A risk of unintended consequences also exists if material is deposited or forms jams where it compromises infrastructure, property, public safety, or existing valuable habitat (refer to *Public Safety* Appendix).

Sustained benefits to fish and wildlife from a managed inputs approach can only be achieved through periodic re-application for as long as the natural supply and delivery of material to the system is constrained. In some instances, supplementation may require a substantial commitment of resources to achieve the desired result in both the short- and long-term, especially in instances where the disturbed processes will likely never be restored. Examples of strategies to address common inputs' constraints on channel and floodplain processes are provided in Table 5.

Table 5. Examples of strategies to address deficient inputs* to stream processes.

Problem	Causes	Strategy	Relevant Techniques
Sediment starved	Dams	Dam removal; Sediment augmentation for small streams	Channel modification, Dedicating land and Water
	Channel armoring	Channel re-naturalization; Sediment augmentation for small streams; Dedicating land	Channel modification, Dedicating land and water
Marine-derived nutrients	Passage barrier	Fish passage restoration (Barrier removal or passage); -Nutrient supplementation	Fish passage (AHG)
Large wood starved	Riparian logging; Channel armoring; Dams/impoundments	Riparian restoration; Channel modifications; Large wood inputs; Dedicating land	Riparian revegetation, Channel modification, Large Wood, Dedicating land and water

* Input deficiency may occur at any scale.

4.7.2 Incised Channels

Channel incision is the progressive lowering of the channel bed relative to its floodplain elevation. Incised channels are transitional forms between one dynamic equilibrium channel form and another[25]. Through typical geomorphic evolution, incised channels commonly expand laterally as they form a floodplain relative to the incised channel elevation. Incision and associated expansion results in the erosion of the bed and banks, the delivery of considerable quantities of sediment to downstream reaches, dewatering of the riparian zone[26], destruction or degradation of existing aquatic habitat[27], and the undermining of infrastructure such as bridges and utility crossings.

Tributaries to incised channels may also incise (i.e., 'headcut') as they adjust to the lower base level of the main channel. This process can propagate long distances upstream and upslope, extending throughout the drainage network. Channel incision processes are further detailed in Chapter 2, the Geomorphology Appendix and in RiverRAT Section 2-6.3, Channel Incision and Evolution, which describes common indicators and management strategies for incised channels. RiverRAT Appendix1.2

Table 6. Examples of strategies and techniques to address channel incision

Problem	Causes	Strategy	Relevant Techniques
Watershed-scale problems, causes and strategies			
Ongoing incision	Urbanization	Stabilize channel; restore flow regime	Channel modification; Instream structures; Dedicating land and water
	Dams or other sediment traps	Stabilize channel; Augment sediment; Remove structure	Channel modification; Instream structures; Large wood, Dedicating land and water
	Removal of wood, beavers, or other natural stabilization	Stabilize channel; restore wood, beavers	Channel modification; Instream structures; Beaver reintroduction; Large wood; Riparian restoration; Dedicating land
	Base level lowered	Stabilize channel and restore base level; Reconfigure channel for new base level	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land and water
Incised channel with stable grade	Urbanization	Lower floodplain; Enhance channel	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land and water
	Dams	Lower floodplain; Enhance channel; Remove structure	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land and water
	Loss of natural stabilization (e.g. large wood jams)	Raise channel grade; Lower floodplain; Restore natural stabilizing features	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land
	Base level lowered	Reconfigure channel for new base level	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating and water
Reach-scale problems, causes and strategies			
Active incision or Incised channel with stable grade	Channelization or Dredging	Restore channel	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land
	Removal of local grade control	Stabilize channel; Restore channel	Channel modification; Instream structures; Large wood; Riparian restoration; Dedicating land

4.7.3 Aggrading Channels

Aggradation is the progressive accumulation of in-channel sediment resulting in increased channel bed elevation. Aggrading channels indicate that an excess of sediment exists relative to a stream system's capacity to transport that sediment and is typically a reach-scale phenomenon. Characteristics of aggrading streams are covered in Chapter 2, the Geomorphology Appendix and RiverRAT Appendix1.2. Channel response to aggradation commonly includes increased rates of bank erosion and lateral migration. Aggradation can impact infrastructure and habitat through increased flood elevations, reduced bridge capacity, channel widening with associated bank erosion, temporary loss of fish habitat, increased summer stream temperature due to decreased depth, or channel migration into developed land.

Aggradation occurs at the point where stream energy is insufficient to transport sediment delivered to a system. In undisturbed watersheds and stream systems, aggradation typically occurs in one of two environments: alluvial fans and deltas. In both cases, aggradation occurs at a break in channel grade, at the point where the stream slope decreases significantly without any change in hydrology, such as at the mouth of a steep canyon (alluvial fan) or at the mouth of a river at a lake or the ocean (delta). Aggradation may also occur in response to reductions in effective discharge (e.g. in regulated rivers), increases in sediment supply (e.g. from excessive erosion due to land use impacts, from in-channel mining, or downstream of a headcut or incising channel), or upstream of channel modifications or

Table 8: Sources of Pollution by Land Use Activities[38]

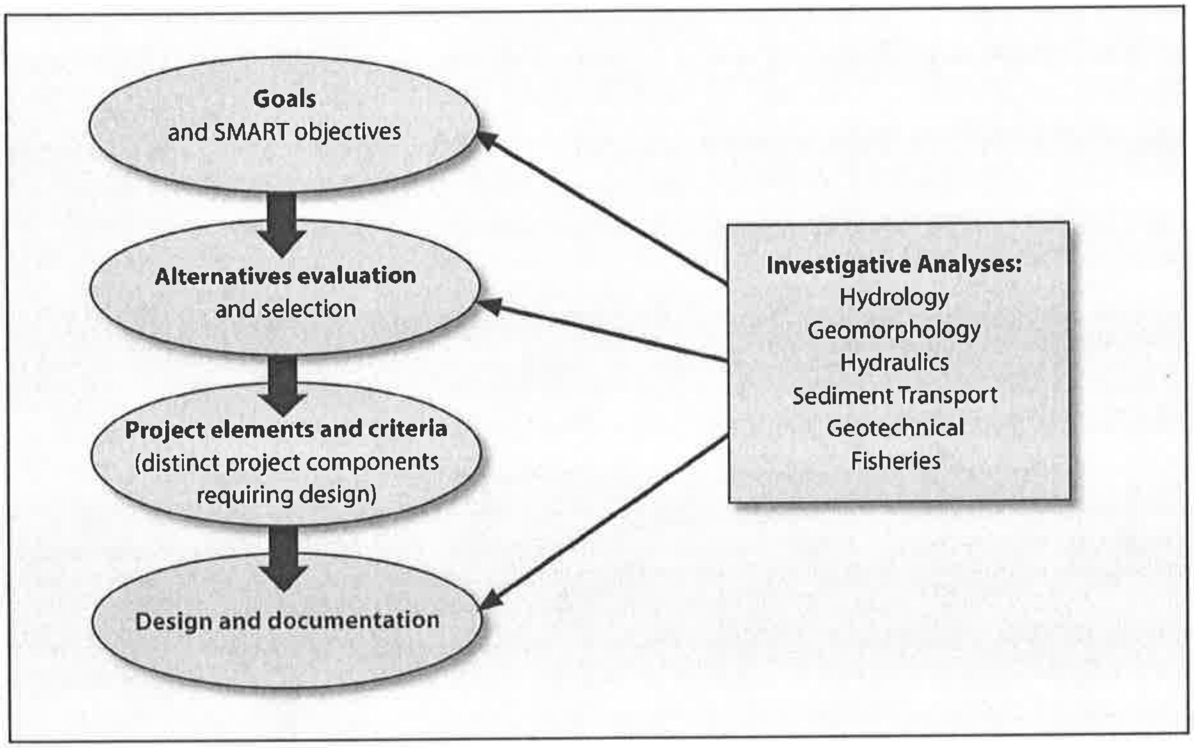
Non-point Source	Nitrogen	Fecal Coliform	Sediments	pH	Dissolved oxygen	Pesticides	Flow	Temperature
Agriculture								
Animal Feeding Operations	X	X	X	X	X			
Dryland	X		X			X		X
Irrigation	X		X	X	X	X	X	X
Non-commercial	X	X	X					X
Forest Practices								
Road construction			X			X	X	X
Timber harvesting			X				X	X
Reforestation	X					X		X
Urban/Rural								
Construction			X					X
On-site sewage systems	X	X		X	X			
Stormwater runoff	X		X	X		X	X	X
Hydromodification								
Channelization			X		X		X	X
Dams			X		X		X	X
Wetlands and riparian Areas								
Vegetative clearing			X		X	X	X	X
Draining of wetlands	X		X				X	X
Recreation								
Marinas and boats	X	X	X	X	X			
Off-road		X	X					
Hiking, fishing		X						

Strategies for addressing water quality impairments are linked to point- or nonpoint sources. Point sources of pollutants are best addressed at the source through improvements to water treatment before it is released to the stream. Non-point sources can be addressed through a combination of riparian buffer zones, dilution, and upland land use best management practices. Riparian zones buffer waterways from disturbances in the watershed; moderate water temperature and, thus, dissolved oxygen concentrations; limit the rate of bank erosion; and provide wood to streams that control the instream storage and transport of sediment and organic matter. Vegetated riparian zones, along with vegetated uplands and wetlands, increase flow complexity and, therefore, travel time to the stream, increasing the opportunity for pollutant uptake, degradation, sorption, and transformation. They filter sediment, pollutants adsorbed by the sediment (e.g., phosphorus, heavy metals), and insoluble pollutants from overland flow and from flood flow. Aerobic and anaerobic processes operating within a wetland allow certain chemicals to volatilize or precipitate out of the water column. And, the accumulation of organic matter that occurs in many wetlands provides a permanent sink for many chemicals. Restoration of riparian buffers (see Riparian Restoration technique) can provide substantial benefit to streams impacted by non-point sources of pollution.

Once the pollutant reaches the stream, its impact on stream water quality depends, in part, upon its dilution by flow. As the amount of water mixing with the pollutant increases, the pollutant's concentration decreases. Thus, activities that remove water from the stream (e.g., for irrigation or domestic or industrial water supply), that regulate flow (e.g., dams), and that limit base flow (e.g., development of impervious surface which limits groundwater recharge opportunities) increase the likelihood of pollutants impacting water quality. Where streamflow has been depleted, strategies to with project objectives. [Note: The process of defining design criteria may warrant iterative development with the selection of project elements; likewise, subsequent design analyses may warrant iterative development with design criteria.]

5. **Design** involves the iterative analyses based on an appropriate technical design approach for each project element and the development of design products necessary for permitting and sufficient to explain and justify proposed designs and guide implementation. Design stages and milestones vary by project, but typically involve a concept level design (see Alternatives), a draft or preliminary design that is integrated with permitting requirements, and a final design. Design plans, specifications, and reports are often prepared at draft and final stages.

Figure 2. The design process. (Adapted from Figure 35 in *RiverRAT* Appendix 2) Technical analyses (referred to as 'Investigative Analyses' in this figure) are developed to support all phases of design.



The discussion of a design process outlined in this chapter emphasizes:

- Selection and development of an adequate level of analysis and design to address causes of problems or constraints identified through preliminary reach-scale and watershed-scale assessments;
- Selection of appropriate technical approach to design based on project goals, existing and predicted watershed processes and ability to characterize these processes;
- Relation of project elements and their design to defined project objectives; and

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design flow will be necessary to ensure individual structures (such as culverts, fishways, and drop structures) provide unobstructed fish passage; a dominant-flow design discharge may be necessary to design channel components that relate to geomorphic function (such as cross-section and planform); and a flood-level design discharge may be necessary to design certain habitat elements within the floodplain (such as off-channel habitat) and project components in the channel or floodplain that are expected to remain stable up to some maximum flood event.

Two classes of design criteria exist – performance criteria and prescriptive criteria. Performance criteria define *what* a project will achieve and the duration of benefits, while prescriptive criteria define *how* the project will be undertaken. Performance criteria "describe the required performance or service characteristics of the finished product or system without specifying in detail the methods to be used in obtaining the desired end result."[7] The difference between the two types of design criteria can be illustrated by considering the following set of paired performance and prescriptive criteria:

Performance Criteria	Prescriptive Criteria
Large wood structures will remain stable through all flows up to the 25-year discharge	Log structures will be constructed with cables and anchors
Constructed habitat will support specified species of juvenile fish for 10 years	Create 10 acres of off-channel rearing habitat varying in depth from 1 to 3 feet
Provide upstream passage for adult chum during all migratory period flows	Install drop structures of 0.8-foot or less at all flows during all migratory period flows
Floodplain inundation of at least 50% of floodplain area will occur with an average frequency of 2 years.	Create a channel with a width:depth ratio of between 12 and 16

<u>Design Criteria and Monitoring</u>

Design criteria developed as performance criteria can facilitate the development of a monitoring plan capable of measuring project performance relative to the established project goals and objectives. For example, performance criteria for a channel modification project intended, in part, to enhance salmonid spawning habitat may include the expectation that a minimum number of redds will be established by a specified species over a specified timeframe. Monitoring plans to evaluate these performance criteria will include redd counts and will document species and timeframe. Monitoring plan and protocol development is further discussed in the *Monitoring* Appendix.

Prescriptive criteria can also be used as the basis of a monitoring plan, though such monitoring is better suited to evaluating the applicability of specific practices to specific circumstances rather than to evaluating project success. For example, prescriptive criteria may dictate the number of logjams placed and the method of anchoring. (In contrast, performance criteria associated with logjams may specify fish use of habitat created by the jams over time). By comparing post-project counts of logjams to pre-project prescriptive criteria, the success of individual project components can be evaluated (e.g., that the prescribed anchoring method was adequate for the setting). However, this may not provide any meaningful information regarding the project objective of providing habitat, as this does not indicate fish or wildlife use. Only *performance* criteria can be used to determine if the project objectives related to fish or wildlife usage of

Table 1. Overview of side channel types. The source of flow and degree of connectivity may change depending on streamflow conditions.

Side Channel Type	Description	Primary source of flow	Degree of connectivity
Mainstem (flow-through) side channels	Mainstem side channels, also referred to as flow-through side channels, include active, secondary channels that are separated from the main channel by a stable island. Mainstem side channels can be active year-round, seasonally, or only during flood flows. Mainstem side channels are subject to the natural dynamics of the mainstem channel, including flooding, channel shifting, bed scour, and woody debris jam formation.	Main river channel. Lotic conditions with flowing water through the channel.	Well connected to river channel processes including scour, deposition, and wood transport. May convey flow year-round or only be active during high seasonal flows.
Backwater channels	Backwater channels are subject to backwater inundation from the main channel and are typically located in low elevation areas within the floodplain. Backwater channels are typically connected with the main channel only at their downstream end. The location of backwater channels determines whether or not they are scoured by high flows.	Main river channel. Backwatered from a downstream hydraulic control in the main channel. Groundwater flow may also contribute. Lentic conditions; although lotic conditions may occur during high flows.	Well connected to the river for fish passage and nutrient exchange, but not typically subject to scour and deposition except during floods. Typically has standing water for a large portion of the year. May dry up during low water conditions.
Groundwater (percolation) channels	Known as percolation (perc) channels, groundwater channels, or spring-fed channels. These are floodplain channels unconnected to the main channel at their upstream end and fed primarily by hyporheic flow, although other sources of groundwater may also be present. These channels are frequently constructed to support salmon spawning, particularly for chum, which seek out the groundwater upwelling conditions in these channels. Depending on location, groundwater channels may be scoured by high flows.	Sourced by hyporheic flow during most of the year. May dry when the water table drops below the channel invert elevation. Lotic conditions.	Generally connected for fish passage via the downstream end. Depending on elevation and degree of separation from the river, may be inundated by river flow during floods and thus subjected to scour and deposition during these periods.
Wall-based channels	Wall-based channels are found along the toe of higher terraces or valley walls. They are typically groundwater-fed but may also receive spring flow and surface flow from an adjacent terrace or valley wall. Wall-based channels are typically not scoured by main channel flows except during large floods.	Groundwater from adjacent terrace, hillslope tributary flow, or hyporheic flow. Lotic conditions.	Mostly protected from active river flows due to higher elevation and lateral separation from the channel. May or may not be connected for fish passage; depends on flow rate and channel conditions (e.g. gradient).
Floodplain ponds	Floodplain ponds are natural or constructed ponds in or above the floodplain such as abandoned gravel pits, mill ponds, river oxbows, and wetlands. They may be supplied by groundwater or surface water from streams, springs, or the mainstem, though they are frequently not connected to the mainstem river. Frequency of inundation by the mainstem depends on elevation and degree of connectivity. Floodplain ponds may be at different successional stages and may range from permanent to seasonally inundated.	All sources are possible, including river, groundwater, hyporheic, or tributary. Lentic conditions.	Mostly protected from active river flows. May or may not be connected for fish passage; depends on flow rate and potential obstructions such as beaver dams. Some ponds may only be connected during floods from dispersed floodplain flow.

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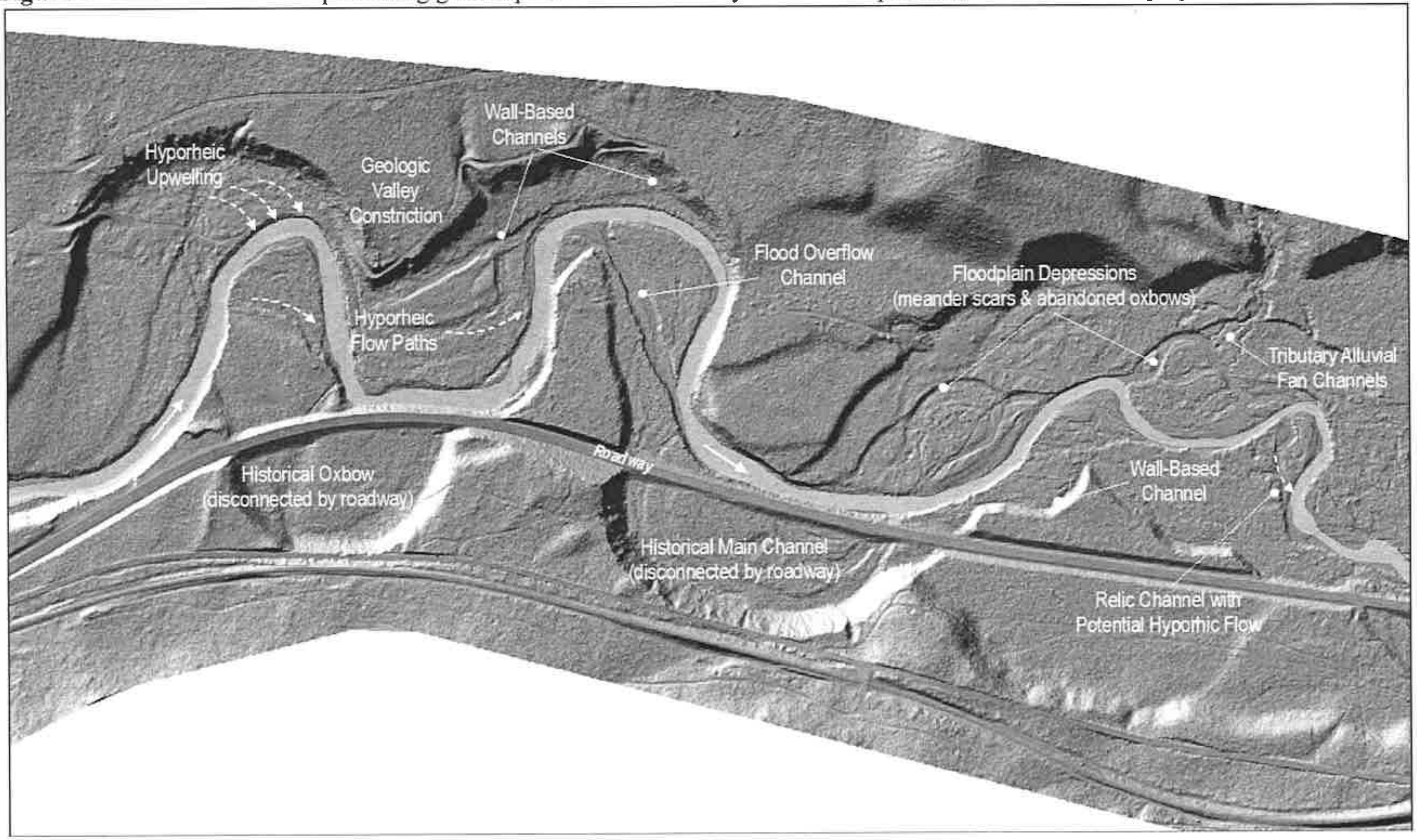
backwater channels that are protected from winter high-flow events. Table 2 includes a number of indicators for locating side channel projects. In order to successfully site and plan a side channel project, these indicators must be paired with a thorough understanding of fluvial geomorphology, aquatic biology, riparian ecology, hydrology, and hydraulics. These are discussed further in Section 5.1.

For most projects, fish utilization in the reach will need to be considered, and for many projects fish use will be the primary restoration objective. Fish use of a specific project may depend on its physical location relative to the spawning distribution of the target species. If the site, for example, is located far above spawning areas, then juvenile use of the area may be limited. If the primary objective is spawning habitat, then the location of the project in relation to the current or potential spawning distribution will need to be considered. For spawning channels, fish supplementation is sometimes used to establish a spawning population. This has been done with chum salmon in the Lower Columbia region.

Table 2. Indicators of potential locations for side-channel projects. See Figure 1 for a visual depiction of some of the more common features that may support side channel restoration.

Valley-scale features
▪ Natural floodplain or valley constrictions may indicate hyporheic upwelling and downwelling that could support the development of groundwater-fed channels. ▪ Areas along the hillslope toe or along the toe of high terraces may indicate locations for potential restoration of wall-based channels. ▪ Alluvial fans often force hyporheic upwelling at their downstream ends. Relatively stable areas near the fan, such as along the lateral margin of the fan, may provide good locations for creation of groundwater-fed channels.
Reach-scale features
▪ Floodplain depressions such as meander scars and abandoned oxbows may indicate opportunities for side-channel creation or restoration. These paleo-channel areas also frequently have coarse subsurface material that may convey hyporheic flow and could support the creation of groundwater-fed channels. ▪ Relic channels at the downstream ends of meander bends are frequently fed by hyporheic flow that flows across the bend and may present good opportunities for groundwater-fed channels. ▪ Degraded (incised) channels may have historical side channels that are perched and could benefit from re-connection with the mainstem through excavation.
Vegetation indicators
▪ Wetland species may indicate channel depressions or shallow groundwater/hyporheic flow that could support groundwater-fed channels. ▪ Early successional species may reveal abandoned channel scars that can be used for side channel locations.
Human features
▪ Abandoned gravel pits may provide good side-channel enhancement opportunities. ▪ Levees or armoring that confines streams may indicate good places to create new side-channel features where they would not be created on their own. ▪ Levees, railroads, or roadways that sever connections with historical channels may present reconnection or enhancement opportunities. Simply restoring fish passage may be highly beneficial in some circumstances.

Figure 1. Hillshaded relief map showing geomorphic features that may indicate the potential for side channel projects.



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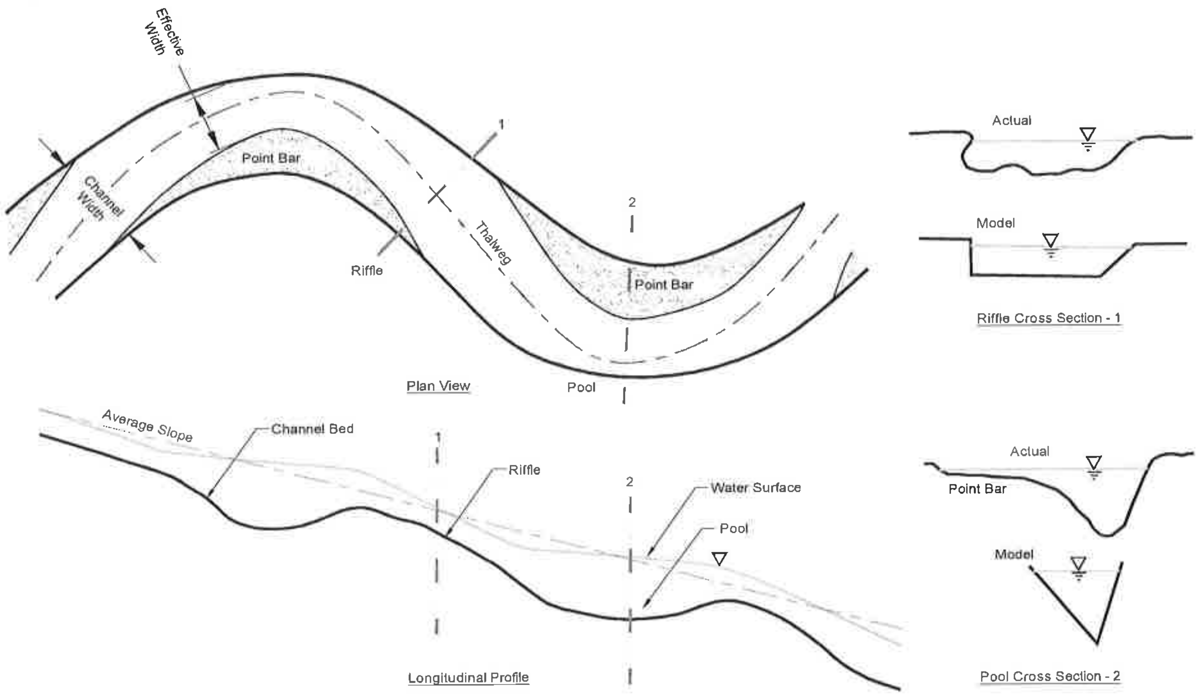
projects, comprehensive data collection and assessment using multiple disciplines will be necessary.

Channel modification design should include reach assessment at a minimum, and watershed assessment in most cases. The scale of the survey should match the scale of problems being addressed, and should make sure to correctly identify and measure the root causes of those problems (refer to Chapter 4 for discussion appropriate strategies to address varying root causes). For instance, restoring a channel that has been over-widened due to grazing, but that is located in an otherwise pristine watershed, may only require a reach-scale analysis. In comparison, restoring a channel that has been over-widened due to elevated sediment supply from upstream forestry activities will require a watershed-scale analysis to make sure future trends in sediment supply are well understood before attempting restoration. Elements of reach- and watershed-scale analyses are presented in Table 4. For further discussion of assessment, refer to SHRG Chapter 3, *Stream Habitat Assessment*.

Table 4. Reach- and watershed-scale data collection and analysis components.

Reach-scale data collection and analysis components
• Topography of project area and adjacent reaches, including floodplain and terraces
• Survey of planform, profile, and cross-sections of existing reach, upstream and downstream reaches, and reference reach (if available) with permanent benchmarks located outside of the construction area
• Sediment characterization of streambed (surface and subsurface) and bank materials of existing reach, upstream and downstream reaches, and reference reach (if available)
• Geomorphic assessment including identification of channel type, channel form, morphological trends, large wood dynamics, and the influence of riparian vegetation (see Section *5.1.1 Fluvial Geomorphology*).
• Evaluation of sediment transport volumes and size distribution (see Section 5.1.4, *Sediment Transport Capacity*). Any channel modifications must be able to accommodate the sediment load without unanticipated adjustments.
• Hydraulic conditions (see Section 5.1.3, *Hydraulics*), including velocity and shear stress of existing channel, flood and overbank flow profiles and floodplain flow patterns (especially channel exit and re-entry areas)
• Mapping of soil materials and vegetation, paying particular attention to soil water regime (ability to support re-vegetation) and soil stability (resistance to mass failure and erosion)
• Evaluation and documentation of the distribution and condition of existing aquatic and riparian habitat. Describe major plant, fish, and wildlife species and communities that may be positively or negatively affected by the project.
• Evaluate bank erosion rates, streambank stability (resistance to mass failure and erosion) and streambed (vertical) stability. Identify active channel incision or aggradation, and the causes of these conditions.
Watershed-scale data collection and analysis components
• Sediment budget for the watershed (identification of sediment sources and routing patterns and quantification on a decadal time scale to assess whether current conditions and proposed design reflect the long-term patterns)
• Watershed hydrology (see Section 5.1.2, *Hydrology*). This includes channel forming discharge, low flows, flood discharges, and design discharges.
• Large wood recruitment, transport and retention
• Riparian function (shade, temperature)
• Point and non-point sources of water quality degradation that may affect project success
• Groundwater/surface water/hyporheic interactions in terms of volume and timing
• Disturbance patterns (frequency and recovery rates from large disturbances such as flood or fire)
• Watershed land-use and the impacts on sediment, flow, water quality, and large woody debris
• Trends in watershed land management and response to management

Figure 1: Channel cross-section in relation to position on longitudinal pool-riffle sequence in an alluvial stream channel. Note how thalweg (deepest point) shifts to outside of bends at pools and remains centered in riffles, and how slope is greater at riffles than at pools. During peak flows, riffle and pool water surface slopes tend to equalize, approaching the average reach slope. Hydraulic and sediment transport models typically use idealized cross-sections and average slopes, as shown.



Channels come in various shapes that are related to the channel type and boundary conditions that characterize the reach. Determination of an appropriate shape may be based on an analog, empirical, or analytical design framework. Self-sustaining channels in nature tend to exhibit consistent relationships between width and depth, cross-sectional area and watershed area, width and pool spacing or meander length, etc. (see discussion of Hydraulic Geometry and Stream Classification in the *Fluvial Geomorphology* Appendix).

5.3.2 Channel Profile and Bedform Considerations

The slope of the bed is typically varied through a reach. It is steepest through riffles or over drops, and shallow or inverse through pools (see Figure 1). The location, spacing, and shaping of these stream channel bedforms (e.g. pools, pool-tailouts, riffles, chutes, etc) is a critically important component of design, and it involves not only profile considerations, but also planform and cross-section considerations. If the stream cannot support the configuration of constructed features, significant erosion, deposition, and re-adjustment may occur, often to the detriment of habitat.

When selecting a channel slope, the designer should consider the topography, the slope of the upstream and downstream channel, and the effects of channel slope on design discharge and

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Figure 2: Channel modification example: Salmon Creek, Jefferson County, Washington. Plan view, showing reach delineation, locations of pools, and large wood complexes.

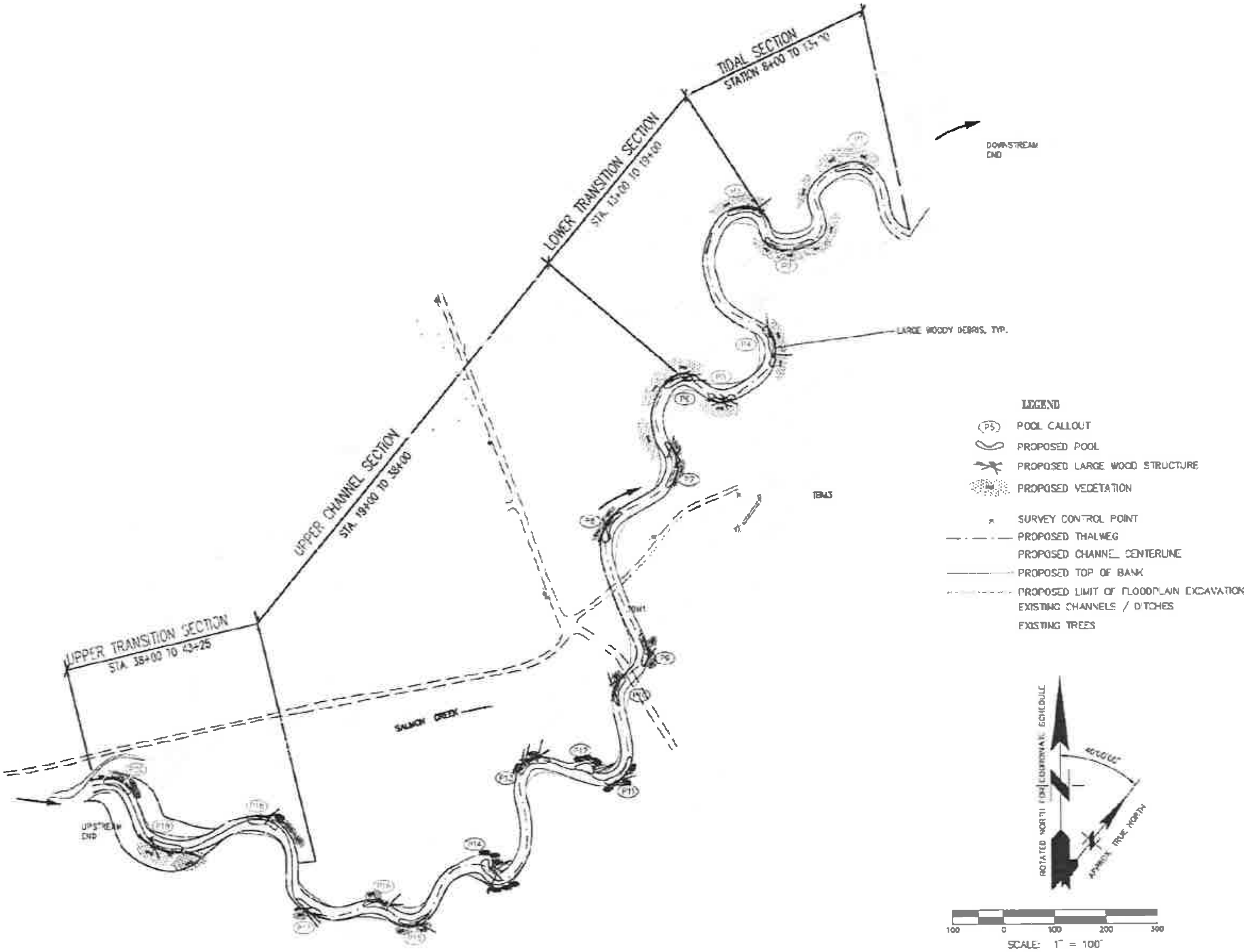

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Figure 9. Results of return chum counts in Salmon Creek before and after restoration, and in Snow Creek, an adjacent watershed. Figure courtesy of the Jefferson County Conservation District.

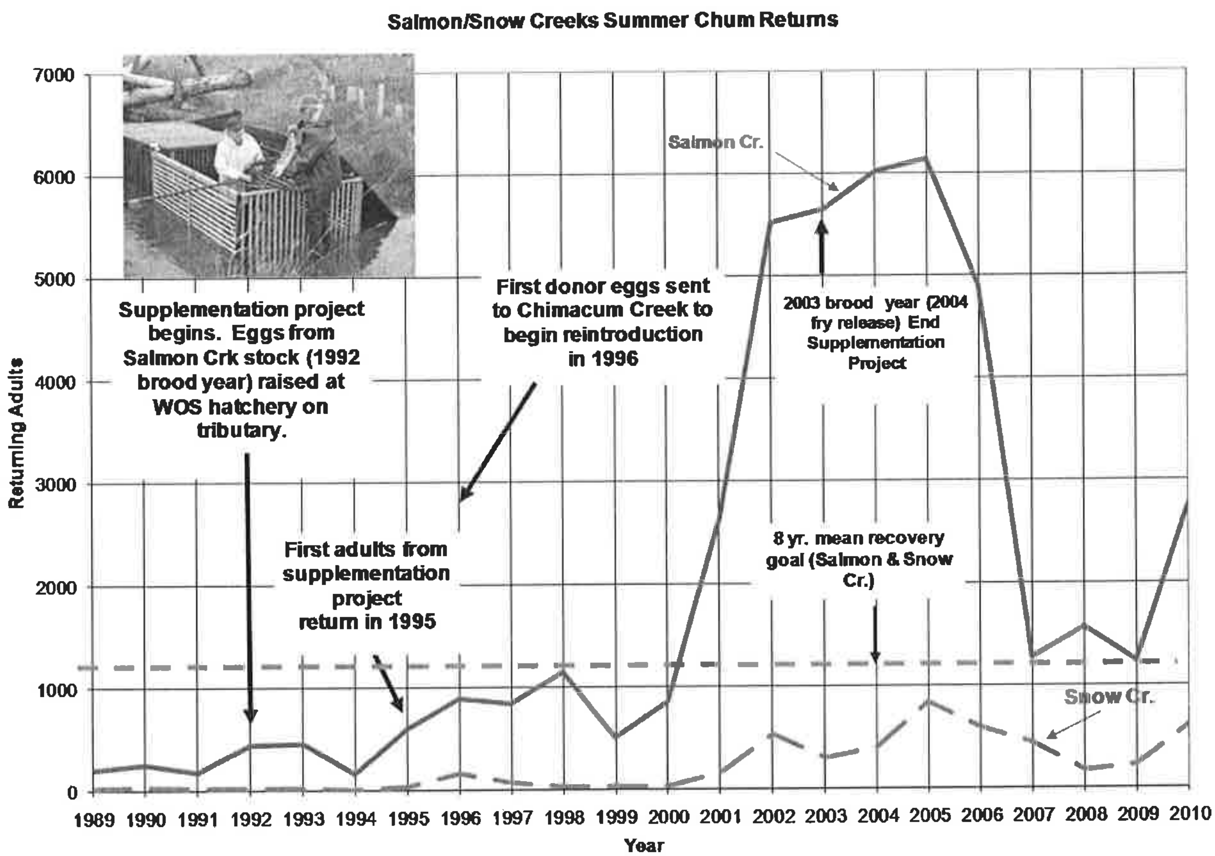

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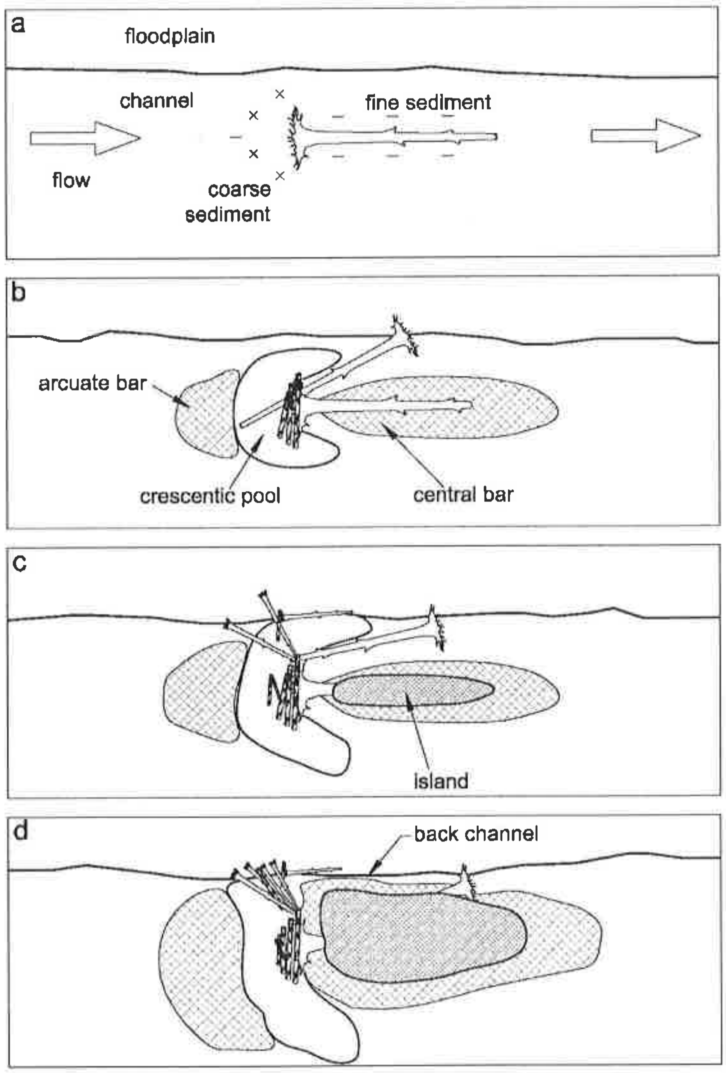
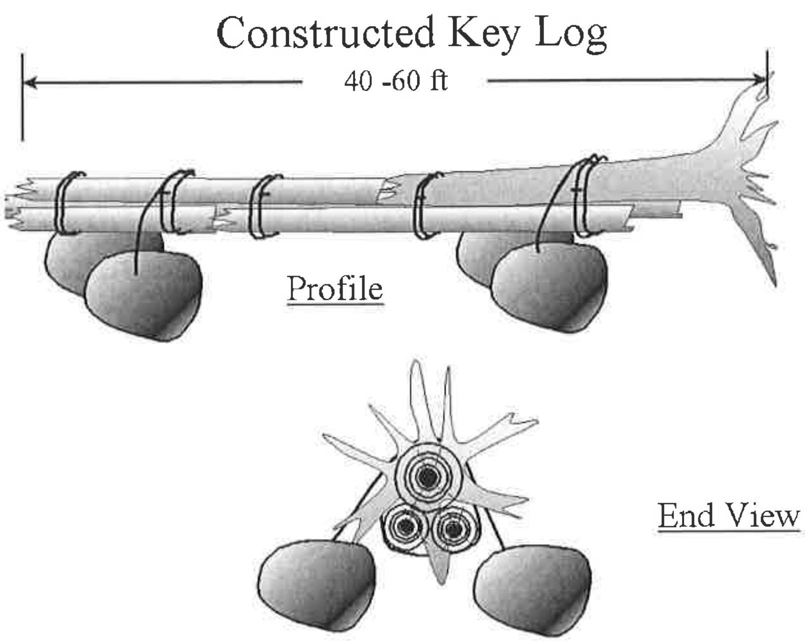
Figure 1. Large Wood and Log Jams. Schematic of side channel formation against the bank at a logjam (courtesy Tim Abbe). Morphological stages in alluvial topography associated with construction of a woody debris (barapex) jam. (a) Deposition of an especially large tree with the root wad intact. (b) Formation of a coarse gravel bar upstream, a crescent-shaped pool immediately upstream of the root wad, and a downstream central bar of finer sediments along the axis of the tree. (c) Island development along the central bar. (d) Integration into the broader floodplain. Modified from Abbe and Montgomery.[21]



Log jams can affect reach-scale channel characteristics. Large log jams or a series of log jams can increase the hydraulic roughness of a reach, thereby reducing average velocity and increasing water surface elevation. Log jams may reduce velocity sufficiently to increase reach-

Figure 9. Large Wood and Log Jams. Concept of constructing LW key piece by cabling together smaller logs. Boulder ballast may or may not be required depending on site conditions (courtesy Tim Abbe).

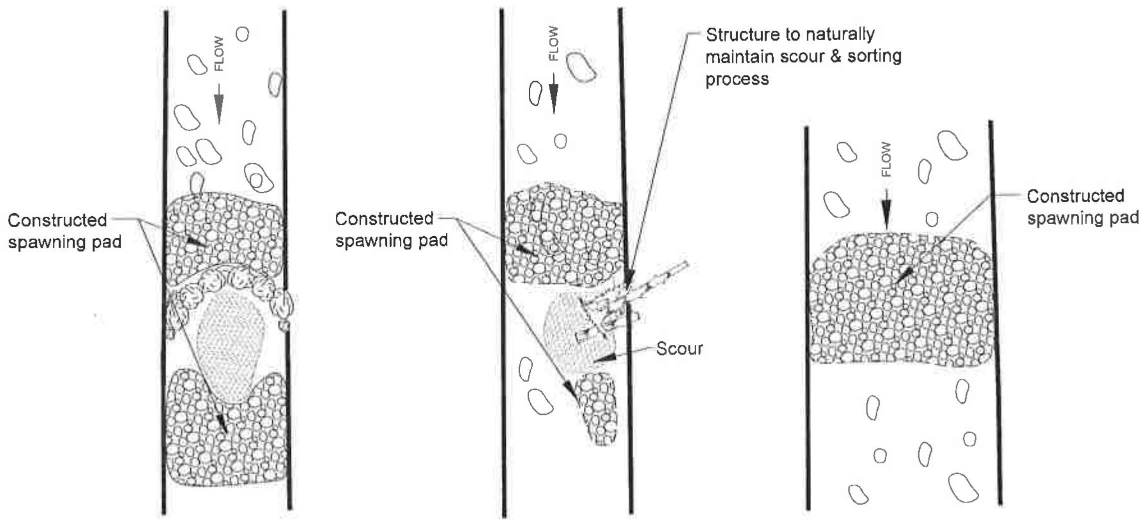


When designing LW and log jam projects, it is critical to understand the size of wood that was historically available to serve as key pieces in the channel. For most streams in Washington, prior to harvest of riparian timber stands, trees were more frequently available to meet or exceed the minimum key piece sizes listed above in Table 1. In many cases, these large trees took many hundreds of years to grow and it will be many hundreds of years from now until they are again available to naturally function as key pieces in the channel. This is especially true for larger streams that require larger trees to serve as key pieces. This lack of available wood for in-channel needs must be considered when planning and designing LW projects. In particular, designing for anchoring and stability will need to consider the lack of future natural recruitment of key pieces, as well as the difficulty in acquiring or importing key piece sized material.

Durability and decay rates will affect the stability and longevity of wood in streams. Differences in the durability between coniferous and hardwood species can be quite dramatic when not fully submerged. Deciduous wood lacks tannins that slow decay. Because of this, they decay much more rapidly and may lose structural integrity within a decade depending on size and the degree of wetting and drying that occurs. However, Bilby et al.[45] found that when hardwood (red alder, big leaf maple) and conifer species (Douglas fir, western red cedar, western hemlock) were fully submerged for five years, the decay rates of the hardwood species were only slightly higher than for conifer species. Of the five species included in the study, western red cedar exhibited the lowest resistance to rupture, whereas big leaf maple exhibited the highest. It is recommended that coniferous species be used for all key pieces of wood that are critical to structure stability and function when not continuously submerged. However, deciduous species could be used to make up a portion of non-key piece members in an effort to reduce costs and provide diverse that were organized into three main categories. These categories included 1) wood that had not moved since entering the channel except for possible rotation (*in-situ* wood debris), 2) wood that had moved downstream as a result of fluvial processes (transport jams), or 3) a combination of the two (typically comprised of stable in-situ key members with smaller material racked against and on top of it). These are described in Table 2. Refer to Abbe and Montgomery[21] for additional information.

Table 2. Jam types observed on the Queets River, Washington. Table modified from Abbe and Montgomery[21] and Abbe [44].

Category	Types	Description
In-situ		
	Bank input	Trees that are fully or partially located within the channel where they fell .
	Log steps	Trees that span the channel with each end being held in place by boulders, bedrock, wood or sediment. Sediment accumulates upstream of the tree and water flows over the top creating a step in the channel profile.
Combination Jams		
	Valley jams	Stable full-spanning jams initiated by one or more stable key members (usually oriented approximately perpendicular to the channel) that constrict a large portion of the bankfull cross-sectional area.
	Flow-deflection jams	Partially spanning jams consisting of one or more key members and large quantities of racked debris. Key members are locally recruited. Flow is deflected nearly perpendicular to the channel axis.
Transport Jams		
	Debris-flow	Jams resulting from the deposition of wood following debris flows. They tend to be chaotic, full-spanning, and retain large amounts of sediment upstream.
	Flood jams	Jams that are mobile during large floods. They may temporarily obstruct the channel and cause backwater followed by re-mobilization. They frequently deposit in the floodplain.
	Bench jams	Partially spanning jams that form along the margins of high gradient headwater channels. They consist of one or more key pieces of wood wedged into bedrock outcrops, boulders, or other obstructions.
	Bar-apex jams	Jams formed at the upstream end of a mid-channel bar or forested island. They can initiate bar and island formation. These jams readily accumulate fluvially transported wood (see **Figure 10**).
	Meander jams	Jams formed on the outside bank at the downstream end of meander bends, primarily in large, low gradient alluvial channels. These jams readily accumulate fluvially transported wood (see **Figure 11**).
	Unstable debris	Mobile wood deposited on banks and on the floodplain during floods. These have a negligible impact on channel morphology and likely continue moving downstream in the next flood event.



Salmonid Spawning Gravel Cleaning and Placement Figure 1. Surface water dominated stream. Conceptual design.

<u>Spawning Gravel Placement</u>
In some cases, spawning gravel may be added to the stream to compensate for an identified loss of the natural gravel supply by constructing discrete spawning pads (See **Salmonid Spawning Gravel Cleaning and Placement Figure 1**) or through gravel supplementation. Depending on the specific conditions (flow, gradient and ambient substrate) both of these techniques may require maintenance and/or repeated application.

Construction of spawning pads is a direct habitat creation approach. Spawning pads are typically created by either building a channel constriction or installing streambed control structures across the channel. These structures may be designed to hold a specific mix of gravel that is placed mechanically or to trap the natural gravels that are mobile during high flows. With the exception of groundwater fed streams and channels, the benefits of these projects may be short lived if conditions are such that gravel is washed from the site over time and there is no compensating replacement from natural sources.

As an alternative to constructing discrete spawning pads, spawning gravel supplementation uses a managed inputs approach to create spawning habitat. In this technique appropriately sized spawning gravel is supplied to the stream and natural hydraulic processes redistribute the material downstream over time. Due to the unpredictability of high flow events capable of redistributing the material, it may take several years before the habitat benefits are realized. Benefits may be long-lived or short-lived, depending on design and on the magnitude and frequency of high flow events. In order to maintain the benefits in the long-term, gravel may need to be added periodically.

salmonids [19]. (This identical table appears the Canadian Fish Habitat Enhancement Guide and is credited to Reiser and Bjornn[20].)

Species	Minimum Depth (m)	Velocity ($m*sec^{-1}$)	Substrate Mix Size Range (mm)	Mean Redd Area (m^2)	Req'd Area per Spawning Pair (m^2)
Fall chinook salmon	0.24	0.30 – 0.91	13 – 102	5.1	20.1
Spring chinook salmon	0.24	0.30 – 0.91	13 – 102	3.3	13.4
Summer chinook salmon	0.30	0.32 – 1.09	13 – 102	5.1	20.1
Chum salmon	0.18	0.46 – 1.01	13 – 102	2.3	9.2
Coho salmon	0.18	0.30 – 0.91	13 – 102	2.8	11.7
Pink salmon	0.15	0.21 – 1.01	13 – 102	0.6	0.6
Sockeye salmon	0.15	0.21 – 1.07	13 – 102	1.8	6.7
Kokanee	0.06	0.15 – 0.91	13 – 102	0.3	0.15
Steelhead	0.24	0.40 – 0.91	6 – 102	4.4 – 5.4	
Rainbow trout	0.18	0.48 – 0.91	6- 52	0.2	
Cutthroat trout	0.06	0.11 – 0.72	6 – 102	0.09 – 0.9	

The observed optimal sediment size distribution for three Pacific salmon species is provided in **Table 2**. For most species of salmonids, the general guideline is approximately 80% of 10 to 50 mm gravel with the remaining 20% made up of 100 mm gravel and a small portion of coarse sand (2 to 5 mm). More specific substrate mixes can be tailored to fish size. Small-bodied salmonids[1] spawn in gravel that is generally between 8 mm and 64 mm in size. Large bodied salmonids[2] spawn in gravel that is generally between 8 mm and 128 mm in size.

Table 2. Average size composition of gravel in redds of three Pacific salmon species (adapted from Andrew and Geen [21] and Burner [22]). Approximate average weight of each species shown in brackets.

Gravel Size (diameter)	Fall-run Chinook (9 kg)	Coho (4 kg)	Sockeye (1.5 kg)
		Percent	
Fines	10	8	12
3 – 12 mm	19	23	23
13 – 50 mm	38	43	51
51 – 100 mm	21	23	12
101 – 150 mm	12	3	2

1 Small-bodied salmonids are defined as species that are typically less than 35 cm long when mature, including resident rainbow, resident cutthroat, anadromous cutthroat, bull trout (Dolly Varden), brown trout, brook trout, and kokanee.
2 Large-bodied salmonids are defined as species that are typically greater than 35 cm when mature, including pink, chum, coho, sockeye, steelhead, and chinook salmon.

Table 4. Geomorphic or hydrologic settings that are likely to be sensitive to climate change impacts, and consequently where stream habitat is likely to be more significantly impacted (adapted from Paul Bakke's unpublished Climate Change Screening Matrix).

Landform or Geomorphic Setting	Identification, Description	Response to climate change	Implications
Response reach	• High volumes of bedload sediment • High unit stream power > 25 w/m^2 • High channel migration rates • Channel avulsions common	• Period of reduced stability • Increased channel migration • Aggradation • Increased scour • Reoccupation of dormant terraces	• Burial by sediment likely • Channel abandonment due to avulsion • Erosion or flooding of recently inactive terraces
Alluvial fan	• Confluence of tributary with lower gradient mainstem • Fluvial gravel or sandy soil • Active fan: water can access top of bank • Dormant fan: channel incised	• Reactivation of dormant alluvial fans • Channel avulsions	• Channel migration & abandonment due to avulsion • Flooding/erosion of historically dry areas
Debris fan	• Confluence of tributary with lower gradient mainstem • Mixed soil: silt/clay to large boulders • Fan "large" relative to stream channel	• Potential increased rate of debris flows	• Increased or high debris flow risk • Increased channel migration due to avulsion
River delta	• Depositional landform where river enters Puget Sound, the Pacific Ocean, or a major lake	• Inundation by rising sea level • Altered (possibly increased) sediment deposition rate • Upstream migration of deltaic zone	• Increased flooding • Increased channel avulsion rate • Loss of floodplain area • Shift in floodplain boundaries to include new areas
Glacial hydrology, source < 2500 m elev.	• Small, lower-elevation glaciers in headwaters (*cirque* glaciers) • Glaciers without extreme precipitation in accumulation zone	• Complete disappearance of glacial ice	• Reduced summer baseflow • Increased summer temp. • Floods shift from spring to fall, winter
Snowmelt hydrology, source < 2500 m elev.	• Headwaters in transient snow zone	• Shift from season-long to transient snowpack • Degradation, increased scour	• Reduced summer baseflow • Increased summer temp. • Floods shift from spring to fall, winter

high sediment transport capacity, and scarcity of in-channel roughness (such as large wood or boulders) precludes development of alluvial deposits.

Figure 16. Montgomery and Buffington stream classification. Longitudinal view and watershed-scale process perspective (Adapted from Montgomery and Buffington.[24] Reproduced with permission of the publisher, the Geological Society of America, Boulder, Colorado, USA. Copyright ©1997).

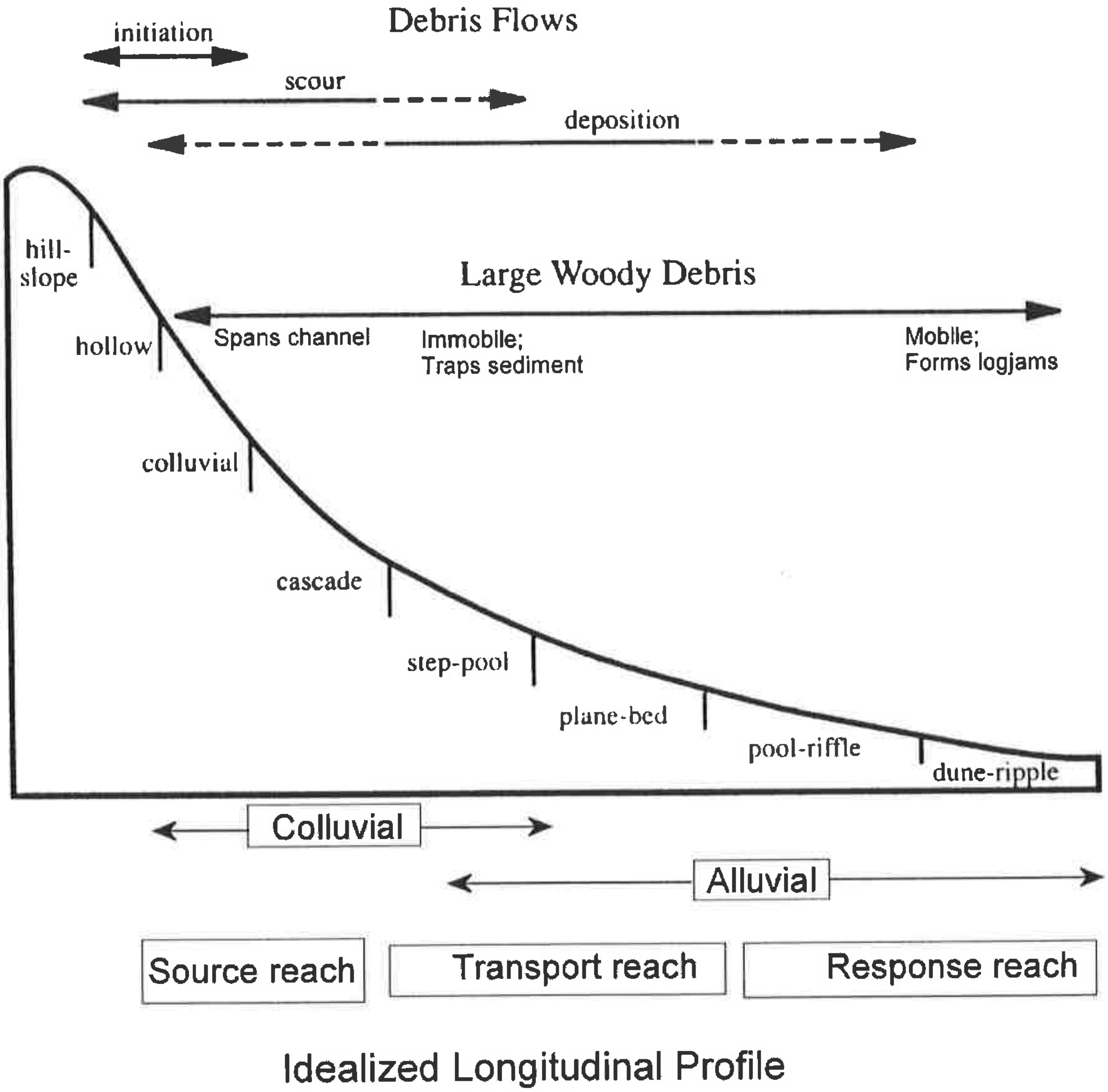


Figure 17. Montgomery and Buffington stream classification. Sketches of selected stream types (Adapted from Montgomery and Buffington.[24] Modified with permission of the publisher, the Geological Society of America, Boulder, Colorado, USA. Copyright ©1997 Geological Society of America).

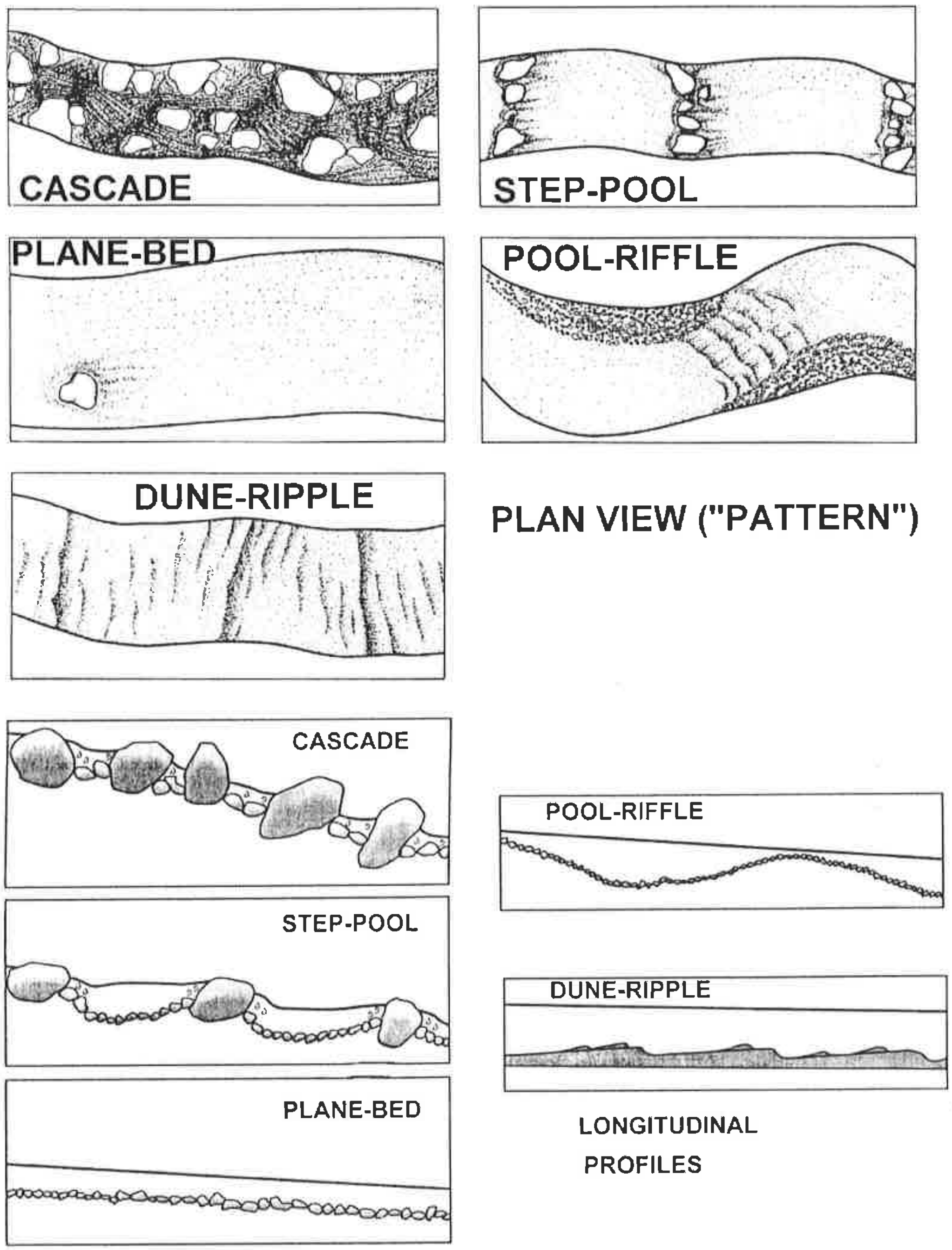


Figure 17. Montgomery and Buffington stream classification. Sketches of selected stream types (Adapted from Montgomery and Buffington.[24] Modified with permission of the publisher, the Geological Society of America, Boulder, Colorado, USA. Copyright ©1997 Geological Society of America).

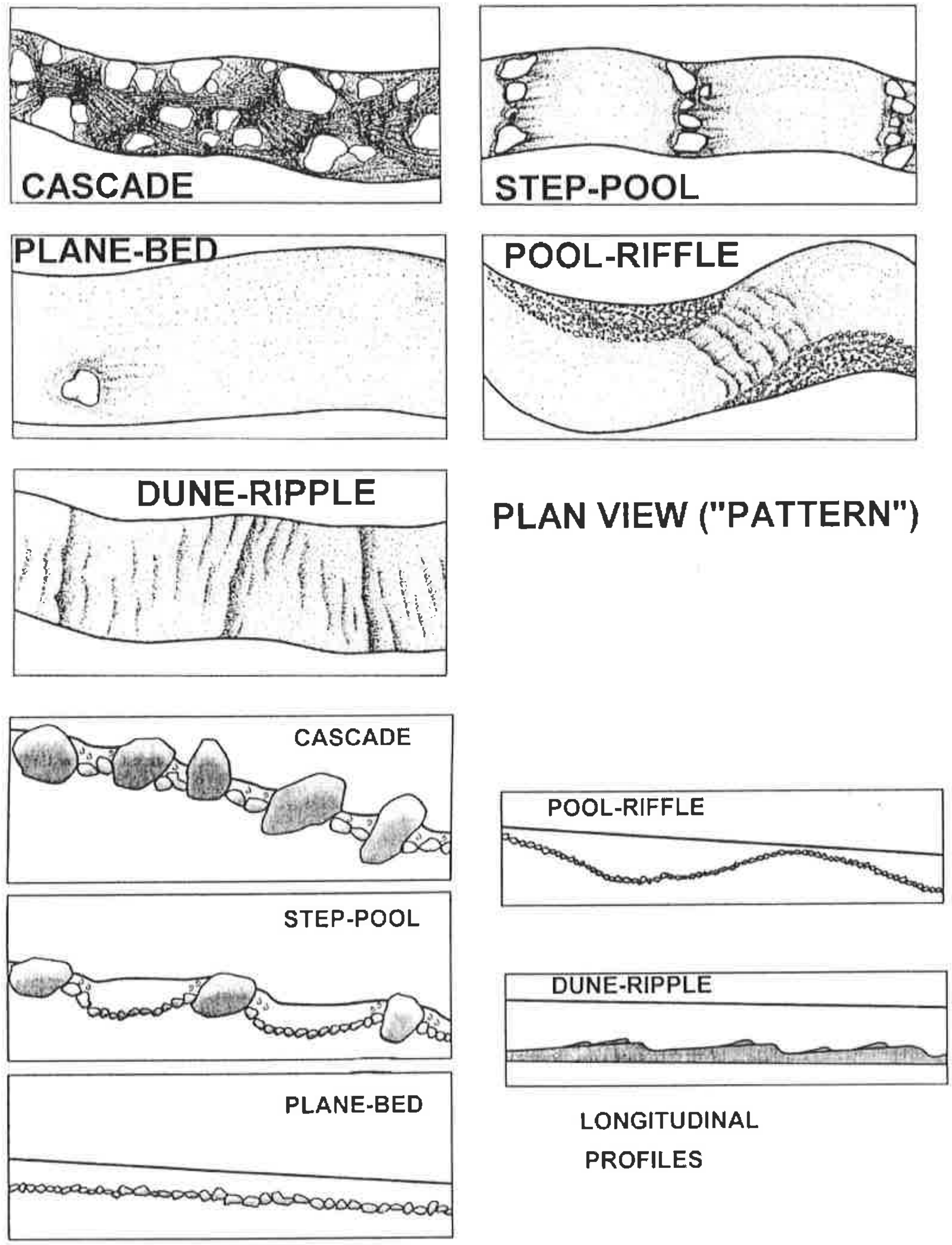
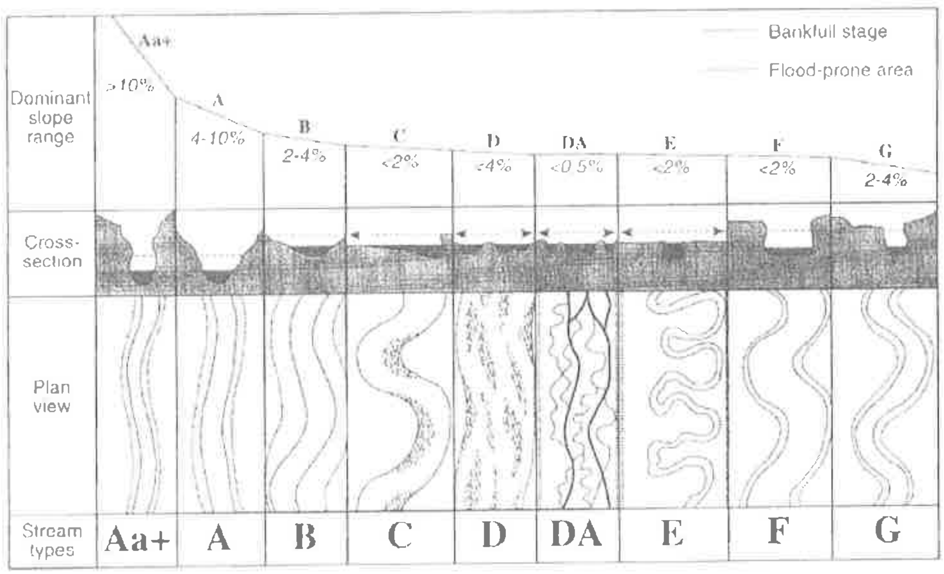


Figure 18. Rosgen stream classification (Adapted from Thorne.[28] Copyright 1997. © John Wiley & Sons Limited. Modified with permission).



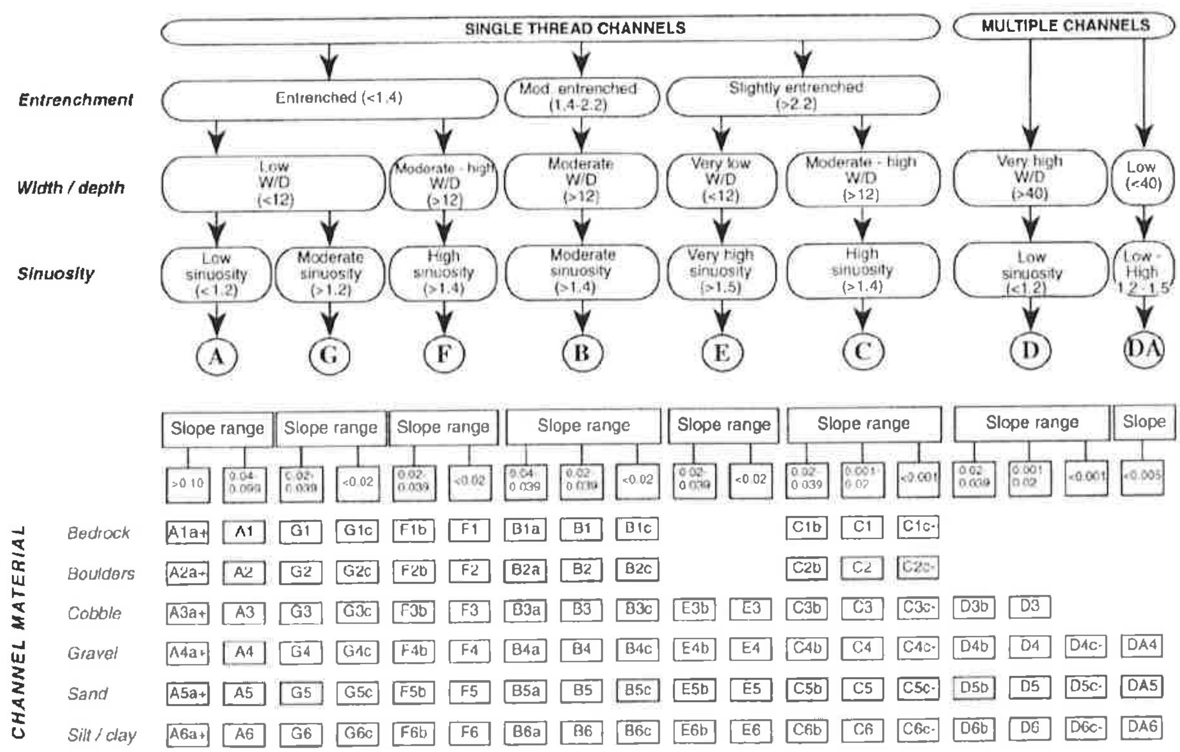


Table 2. Reconnaissance-level geomorphic assessment. Which elements are appropriate for a given investigation depends on the type and size of river, its geomorphic setting, and the type of proposed management or restoration.

Investigation	Objective	Tools/Tasks
Geomorphic or valley setting	Characterize setting and associated landforms	Aerial photos, topographic maps, watershed analyses, geology reports or maps, soil survey reports
Geomorphic reconnaissance	Map and characterize channel-adjacent surfaces (floodplain, terraces, erosional surfaces)	Field survey Soil profiles Vegetation survey including age of woody plants and riparian successional status of various communities.
Hydrological assessment	Characterize hydrological regime	USGS[H] or other (state, city, county) stream gage data Peak flow analysis and flood history
Streambank erosion survey	Document streambank condition and erodibility	Field surveys, documenting bank materials, angle of bank surfaces, rooting depth and density, vegetative cover, natural and man-made armor, style of erosion, directly measured erosion rates from cross sections or erosion pins Protocols: BEHI.[I] Link changes observed to flood history if available.
Sediment deposition survey	Document recent deposition history	Field surveys, documenting pool infilling, fresh in-channel and floodplain deposition depths, mid-channel and transverse bar development. Link changes observed to flood history if available.
Channel migration assessment	Document style and rate of channel migration over historical record	Time sequence of aerial photos, old surveys such as the GLO[J] surveys. Link changes observed to flood history if available.

[H]United States Geological Survey

[I]BEHI is the bank erosion hazard index, a protocol developed by Rosgen.[27]

[J]GLO is the General Land Office, a former government agency that conducted land plat and transect surveys in the nineteenth and early twentieth centuries over much of the western United States.

APPENDIX B
DEFINITIONS

Anadromous Fish – Fish that spawn and rear in freshwater and mature in the marine environment. While most Pacific salmonids die after their first spawning, adult char (bull trout), cutthroat trout and steelhead can live for many years, moving in and out of saltwater and spawning each year. The life history of Pacific salmonids contains critical periods of time when these fish are more susceptible to environmental and physical damage than at other times. The life history of salmonids, for example, contains the following stages: upstream migration of adults, spawning, inter-gravel incubation, rearing, smoltification (the time period needed for juveniles to adjust their body functions to live in the marine environment), downstream migration, and ocean rearing to adults (WDCTED 2003).

Anadromous Fish Habitat – Habitat that is used by anadromous fish at any life stage at any time of the year, including potential habitat likely to be used by anadromous fish that could be recovered by restoration or management and includes off-channel habitat (WDCTED 2003).

Alevin – Newly hatched salmon; yolk sac is still attached (Merz et al. 2008).

Benthic – Pertaining to the bottom (of estuaries, rivers, streams, and lakes) (Merz et al. 2008).

Best Available Science – Current scientific information used in the process to designate, protect, or restore critical areas that is derived from a valid scientific process as defined by WAC 365-195-900 through 925. Sources of the best available science are included in Citations of Recommended Sources of Best Available Science for Designating and Protecting Critical Areas published by the Washington State Department of Commerce (WDCTED 2003). Other sources of best available science included the state aquatic habitat guidelines program, WDFW priority, habitats, and species management recommendations, Puget Sound Nearshore Ecosystem Restoration Project, the National Academy of Science Report and the State of Washington Department of Ecology best available wetland science document, to name a few.

Best Management Practices (BMPs) – Conservation practices or systems of practices and management measures that: (A) Control soil loss and reduce water quality degradation caused by high concentrations of nutrients, animal waste, toxics, and sediment; (B) Minimize adverse impacts to surface water and ground water flow and circulation patterns and to the chemical, physical, and biological characteristics of wetlands; (C) Protect trees and vegetation designated to be retained during and following site construction and use native plant species appropriate to the site for re-vegetation of disturbed areas; and (D) Provide standards for proper use of chemical herbicides within critical areas. The [city/county] shall monitor the application of best management practices to ensure that the standards and policies of this Title are adhered to (WDCTED 2003).

Buffer or Buffer Zone – An area that is contiguous to and protects a critical area which is required for the continued maintenance, functioning, and/or structural stability of a critical area (WDCTED 2003).

Channel Migration Zone (CMZ) – The lateral extent of likely movement along a stream or river during the next one-hundred (100) years as determined by evidence of active stream channel movement over the past one-hundred (100) years. Evidence of active movement over the one-hundred (100) year time frame can be inferred from aerial photos or from specific channel and valley bottom characteristics. The time span typically represents the time it takes to grow mature trees that can provide functional large woody debris to streams. A CMZ is not typically present if the valley width is generally less than two (2) bankfull widths, if the stream or river is confined by terraces, no current or historical aerial photographic evidence exists of significant channel movement, and there is no field evidence of secondary channels with recent scour from stream flow or progressive bank erosion at meander bends. Areas separated from the active channel by legally existing artificial channel constraints that limit bank erosion and channel avulsion without hydraulic connections shall not be considered within the CMZ (WDCTED 2003).

Channelized stream – A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course (Knutson and Naef 1997).

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Chinook – The largest species of the Pacific salmon, also commonly called "King." Adults weigh about 22 pounds (10kg) and are generally 36 inches (91cm) long. Some Chinook can exceed 100 pounds (Merz et al. 2008).

Chum – A species of Pacific salmon. Chum are also referred to as dog salmon because they were commonly dried and used for feeding dog teams during winter. Chum migrate to sea shortly after spawning in lower river systems. Normal/max size is 26 inches (65cm) and 13 pounds (6kg) (Merz et al. 2008).

Coho – A species of Pacific salmon. Coho typically spawn in coastal streams. Historically coho spawned in Idaho, but due to dams are now extinct everywhere but coastal streams. Normal/max size is 30 inches (75cm) and 13 pounds (6kg) (Merz et al. 2008).

Cumulative Impacts or Effects – The combined, incremental effects of human activity on ecological or critical areas functions and values. Cumulative impacts result when the effects of an action are added to or interact with other effects in a particular place and within a particular time. It is the combination of these effects, and any resulting environmental degradation, that should be the focus of cumulative impact analysis and changes to policies and permitting decisions (WDCTED 2003).

Dissolved oxygen (DO) – The amount of oxygen dissolved in a liquid, such as water (Merz et al. 2008).

Drift Cell – Littoral drift, or shore drift, is the process by which beach sediment is moved along the shoreline. Drift results primarily from the oblique approach of wind-generated waves and can therefore change in response to short-term (daily, weekly, or seasonally) shifts in wind direction. Over the long term, however, many shorelines exhibit a single direction of net shore drift. Net shore-drift is determined through geomorphologic analysis of beach sediment patterns and of coastal landforms (State of Washington Department of Ecology, *http://www.ecy.wa.gov/services/GIS/data/shore/driftcells.htm*).

Ecosystem – A biological community made up of land and water and organisms all interacting together (Merz et al. 2008).

Emergence – The time when the fry leave their gravel nest and move into the water column (Merz et al. 2008).

Estuary – A semi-protected coastal body of water where saltwater is measurably diluted with fresh water (Pritchard 1967 within Simenstad et al. 1982).

Evolutionarily Significant Unit (ESU): The smallest biological unit that can be considered to be a species under the Endangered Species Act as administered by the National Marine Fisheries Service (NMFS). A population or population group is considered to be an ESU if 1) it is substantially reproductively isolated from other conspecific population units, and 2) it represents an important component in the evolutionary legacy of the species. USFWS uses a similar term and concept called the distinct population segment (DPS), which is the wording used in the ESA itself. Thus, the ESU is the NMFS' interpretation of a DPS (WDFW 2008).

Fines – Ambiguous definition of small sediment (roughly <6mm diameter) that may clog inter-gravel pores, impacting permeability and hyporheic water quality (Merz et al. 2008). Fine sediment suffocates eggs and entombs alevins.

Fingerling – Salmonids usually at the parr stage of development (Merz et al. 2008).

Flood or Flooding – A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland waters and/or the unusual and rapid accumulation of runoff of surface waters from any source (WDCTED 2003).

Floodplain – The total land area adjoining a river, stream, watercourse, or lake subject to inundation by the base flood (WDCTED 2003).

Floodplain connectivity – Connection of river to floodplain features such as riparian forests, side channels, sloughs and wetlands (Merz et al. 2008).

Floodway – The channel of a river or other watercourse and the adjacent land area that must be reserved in order to discharge the base flood without cumulatively increasing the surface water elevation more than one (1) foot. Also known as the "zero rise floodway" (WDCTED 2003).

Flows – The rate at which a volume of water passes a given point in a stream or river; usually measured in cubic feet per second (cfs) (Merz et al. 2008).

Frequently Flooded Areas – Lands in the floodplain subject to a one percent (1%) or greater chance of flooding in any given year and those lands that provide important flood storage, conveyance, and attenuation functions, as determined by the [director] in accordance with WAC 365-190-080(3). Frequently flooded areas perform important hydrologic functions and may present a risk to persons and property. Classifications of frequently flooded areas include, at a minimum, the 100-year floodplain designations of the Federal Emergency Management Agency and the National Flood Insurance Program (WDCTED 2003).

Fry – Early lifestage of salmonids. Typically juveniles that can swim and catch their own food. Next life stage after alevin, and before smolt. The third freshwater stage of salmonid development; when egg mass is no longer present and fish develops characteristic markings usually within weeks of hatching. Upon reaching 1.25 inches in length, fish are sometimes called "fingerlings" or "parr" (Merz et al. 2008).

Functions and Values – The beneficial roles served by critical areas including, but are not limited to, water quality protection and enhancement; fish and wildlife habitat; food chain support; flood storage, conveyance and attenuation; ground water recharge and discharge; erosion control; wave attenuation; protection from hazards; historical, archaeological, and aesthetic value protection; educational opportunities; and recreation. These beneficial roles are not listed in order of priority. Critical area functions can be used to help set targets (species composition, structure, etc.) for managed areas, including mitigation sites (WDCTED 2003).

Geologically Hazardous Areas – Areas that may not be suited to development consistent with public health, safety, or environmental standards, because of their susceptibility to erosion, sliding, earthquake, or other geological events as designated by WAC 365-190-080(4). Types of geologically hazardous areas include: erosion, landslide, seismic, mine, and volcanic hazards (WDCTED 2003).

Gravel – Round rocks (64- 2mm) within the streambed which are sometimes used by salmonids in the building of a redd (Merz et al. 2008).

Ground Water – Water in a saturated zone or stratum beneath the surface of land or a surface water body (WDCTED 2003). Groundwater in the floodplain is called hyporheic.

Habitat – The sum total of all the living and non-living factors that surround and potentially influence a plant or animal. Most salmonid habitats are described in terms of physical features such as water depth, temperature, velocity or sediment type (Merz et al. 2008).

Habitat Management Plan – A habitat management plan is prepared by a qualified professional and must identify existing conditions and how the management plan will improve habitat functions over existing conditions to ensure no net loss of salmonid habitat functions. A five year monitoring plan must be included.

Homing – The behavior of returning to the stream where an individual salmonid was hatched (Merz et al. 2008).

Hydraulic Project Approval (HPA) – A permit issued by the Washington Department of Fish and Wildlife for modifications to waters of the state in accordance with Chapter 75.20 RCW (WDCTED 2003).

Hyporheic Zone – The saturated substrata beneath a stream or river channel and under the riparian zone where groundwater and surface water mix (May 2003).

Impervious Surface – A hard surface area that either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development or that causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled macadam or other surfaces which similarly impede the natural infiltration of stormwater (WDCTED 2003).

Incubation – The period of time (variable dependent on temperature) from when an egg is fertilized until swim-up (Merz et al. 2008).

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Landslide Hazard Areas – Areas that are potentially subject to risk of mass movement due to a combination of geologic landslide resulting from a combination of geologic, topographic, and hydrologic factors. These areas are typically susceptible to landslides because of a combination of factors including: bedrock, soil, slope gradient, slope aspect, geologic structure, ground water, or other factors (WDCTED 2003).

Large Woody Debris – Logs or rootwads typically >1 m in length and >10 cm in diameter. Provide important features that support several salmonid life stages and macroinvertebrate production (Merz et al. 2008).

Littoral zone – The region of land bordering a body of water (Merz et al. 2008).

Migrating – Moving from one place to another to live, mate or breed (Merz et al. 2008).

Mitigation – Avoiding, minimizing, or compensating for adverse critical areas impacts. Mitigation, in the following sequential order of preference, is: (A) Avoiding the impact altogether by not taking a certain action or parts of an action; (B) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps, such as project redesign, relocation, or timing, to avoid or reduce impacts; (C) Rectifying the impact to wetlands, critical aquifer recharge areas, and habitat conservation areas by repairing, rehabilitating, or restoring the affected environment to the conditions existing at the time of the initiation of the project; (D) Minimizing or eliminating the hazard by restoring or stabilizing the hazard area through engineered or other methods; (E) Reducing or eliminating the impact or hazard over time by preservation and maintenance operations during the life of the action; (F) Compensating for the impact to wetlands, critical aquifer recharge areas, and habitat conservation areas by replacing, enhancing, or providing substitute resources or environments; and (G) Monitoring the hazard or other required mitigation and taking remedial action when necessary. Mitigation for individual actions may include a combination of the above measures (WDCTED 2003).

Natal stream – Stream of birth (Merz et al. 2008).

Native Vegetation – Plant species that are indigenous to the area (WDCTED 2003).

Natural Production: Fish that spawn or rear entirely in the natural environment. These fish maybe the offspring of natural or hatchery production (WDFW 2008).

Natural Stock: Fish that are produced by spawning and rearing in the natural habitat, regardless of parentage (WDFW 2008).

No Net Loss – No net loss means that the impacts of land use and/or development, whether permitted or exempt from permit requirements, be identified and mitigated such that there are no resulting adverse impacts on ecological functions, habitats or processes (Jefferson County Draft SMP, December 2008).

Ordinary High Water Mark (OHWM) – That mark which is found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, that the soil has a character distinct from that of the abutting upland in respect to vegetation (WDCTED 2003).

Parr – Young salmonid with large, oval, dark marks (that may or may not be present) on sides. Parr marks are believed to be used for camouflage. Parr usually live in freshwater for 1 to 2 years. Parr marks usually disappear during the smolting process (Merz et al. 2008).

Pelagic – Of or in the open ocean or open water (Merz et al. 2008).

Pink - A species of Pacific salmon with very large spots on back and large oval block blotches on both lobes of tail. Spawning adults take on a dull gray coloration on back and upper side with a creamy-white color below. Also known as humpbacks or "humpies", males develop a pronounced hump on backs as they near spawning (Merz et al. 2008). Pink salmon live for only two and a half years.

Pool – A relatively deep, still section in a stream (Merz et al. 2008).

Population: A group of interbreeding salmonids of the same species of hatchery, wild, or unknown parentage that have developed a unique gene pool, that breed in approximately the same place and time, and whose progeny tend to return and breed in approximately the same place and time. They often, but not always, are separated from another population by genotypic or demographic characteristics (WDFW 2008).

Qualified Professional – A person with experience and training in the pertinent scientific discipline (fisheries, wetland science, freshwater biology, marine biology, or hydrogeology). A qualified professional must have obtained a B.S. or B.A. or equivalent degree in biology, environmental studies, fisheries, geomorphology or related field, two years of related professional work experience, and experience assessing habitat impacts and drafting management recommendations to avoid no net loss (WDCTED 2003).

Rearing habitat – Rivers, streams, estuaries, or nearshore areas where juvenile fish find the food and shelter they need in order to grow (Merz et al. 2008).

Redd – A salmonid nest; dug out of the streambed's gravel by adult female (Merz et al. 2008).

Refugia – Habitat sanctuaries from extreme environmental events (Merz et al. 2008).

Restoration – Measures taken to restore an altered or damaged natural feature including: (A) Active steps taken to restore damaged wetlands, streams, protected habitat, or their buffers to the functioning condition that existed prior to an unauthorized alteration; and (B) Actions performed to reestablish structural and functional characteristics of the critical area that have been lost by alteration, past management activities, or catastrophic events (WDCTED 2003).

Riffle – A shallow gravel area of a stream that is characterized by increased velocities and gradients (Merz et al. 2008). Riffle crests/pool tailouts are where most salmonid spawn.

Riparian Habitat – Areas adjacent to aquatic systems with flowing water that contain elements of both aquatic and terrestrial ecosystems that mutually influence each other. The width of these areas extends to that portion of the terrestrial landscape that directly influences the aquatic ecosystem by providing shade, fine or large woody debris, nutrients, organic and inorganic debris, terrestrial insects, or habitat for riparian-associated wildlife. Widths are measured from the ordinary high water mark or from the top of bank if the ordinary high water mark cannot be identified. It includes the entire extent of the floodplain and the extent of vegetation adapted to wet conditions as well as adjacent upland plant communities that directly influence the stream system. Riparian habitat areas include those riparian areas severely altered or damaged due to human development activities (WDCTED 2003).

Riparian vegetation – Vegetation that requires the continuous presence of water, or conditions that are more moist than normally found in the area (Knutson and Naef 1997).

Run – (A)The movement of fish inshore or upstream for spawning, usually at a specific time period (e.g., fall-run, spring-run, winter-run) (Merz et al. 2008); or (B) An area of a stream characterized by smooth surface, moderate depth, and moderate current velocity (intermediate between a pool and a riffle).

Salmonid – Fish that belong to the Salmonidae family, including salmon, trout, char, whitefish, grayling, as well as similar Eurasian species (Merz et al. 2008).

Shorelines – All of the water areas of the state as defined in RCW 90.58.030, including reservoirs and their associated shorelands, together with the lands underlying them except: (A) Shorelines of statewide significance; (B) Shorelines on segments of streams upstream of a point where the mean annual flow is twenty cubic feet per second (20 cfps) or less and the wetlands associated with such upstream segments; and (C) Shorelines on lakes less than twenty (20) acres in size and wetlands associated with such small lakes (WDCTED 2003).

Shorelands or Shoreland Areas – Those lands extending landward for two hundred (200) feet in all directions as measured on a horizontal plane from the ordinary high water mark; floodways and contiguous floodplain areas landward two hundred (200) feet from such floodways; and all wetlands and river deltas associated with the streams, lakes, and tidal waters which are subject to the provisions of Chapter 90.58 RCW, Shoreline Management Act (WDCTED 2003).

Smolt – Life stage when young salmonids often migrate downstream from freshwater to saltwater. When parr become smolts, they lose their spots and turn silvery. Distinct physiological change allows the smolting salmonid to live in saltwater (Merz et al. 2008).

Smoltification – Process of morphological and physiological adjustment that young salmonids of a certain size undergo to live in saltwater. The process includes changes in shape, color and density (Merz et al. 2008).

Sockeye – A species of Pacific salmon also known as the "red" salmon. Dark blue-black back with silvery sides; no distinct spots on backs, dorsal fins, or tails. Spawning adults develop dull, green colored heads with brick red to scarlet bodies. The landlocked version is known as "kokanee" (Merz et al. 2008). Most populations of sockeye include lake or reservoir rearing for at least two years.

Spawn – To bring forth a new generation of salmonid by digging nests in the stream bed and depositing fertilized eggs into them (Merz et al. 2008).

Special Flood Hazard Areas – The land in the floodplain within an area subject to a one percent (1%) or greater chance of flooding in any given year. Designations of special flood hazard areas on flood insurance map(s) always include the letters A or V (WDCTED 2003). Zone A includes areas subject to inundation by the 1-percent-annual-chance flood event and zone V includes areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves. Mandatory flood insurance purchase requirements apply in both zones. (FEMA National Flood Insurance Program, *http://www.fema.gov/business/nfip/fhamr.shtm*).

Species, Candidate – Any fish or wildlife species that is native to the State of Washington that will be reviewed by the Washington Department of Fish and Wildlife for possible state listing as endangered, threatened, or sensitive. A species will be considered for candidate listing if evidence suggests its status meets the criteria for endangered, threatened, or sensitive listings. Candidate species will be managed by WDFW, as needed to ensure the long-term survival of populations in Washington (Knutson and Naef 1997).

Species, Endangered – Any fish or wildlife species that is native to the State of Washington that is seriously threatened with extinction throughout all or a significant part of its range (Knutson and Naef 1997). (Federal definition in the

1973 Endangered Species Act available at: *http://www.fws.gov/endangered/whatwedo.html*.)

Species, Sensitive – Any fish or wildlife species that is native to the State of Washington that is vulnerable or declining, and are likely to become endangered or threatened throughout all or a significant part of its range, without cooperative management or the removal of threats (Knutson and Naef 1997).

Species, Threatened – Any fish or wildlife species that is native to the State of Washington that is likely to become endangered within the foreseeable future throughout all or a significant part of its range (Knutson and Naef 1997). (Federal definition in the 1973 Endangered Species Act available at: *http://www.fws.gov/endangered/whatwedo.html*.)

Steelhead – The anadromous form of the rainbow trout. A small percentage are repeat spawners (Merz et al. 2008).

Stock: A group of fish within a species, which is substantially reproductively isolated from other groups of the same species (WDFW 2008).

Turbidity – The measurement of suspended particles within the water column. Turbidity affects the amount of light penetration in the water column and can impair gill functions in fish (Merz et al. 2008).

Urban Growth – "Urban growth" refers to growth that makes intensive use of land for the location of buildings, structures, and impermeable surfaces to such a degree as to be incompatible with the primary use of land for the production of food, other agricultural products, or fiber, or the extraction of mineral resources, rural uses, rural development, and natural resource lands designated pursuant to RCW 36.70A.170 (RCW 36.70A.030 in part).

Velocity – The speed of flowing water (Merz et al. 2008).

Water Resource Inventory Area (WRIA) – One of sixty-two (62) watersheds in the State of Washington, each composed of the drainage areas of a stream or streams, as established in Chapter 173-500 WAC as it existed on January 1, 1997 (WDCTED 2003).

Watercourse – Any portion of a channel, bed, bank, or bottom waterward of the ordinary high water line of waters of the state including areas in which fish may spawn, reside, or through which they may pass, and tributary waters with defined beds or banks, which influence the quality of fish habitat downstream. This definition includes watercourses that flow on an intermittent basis or which fluctuate in level during the year and applies to the entire bed of such watercourse whether or not the water is at peak level. This definition does not include irrigation ditches, canals, stormwater run-off devices, or other entirely artificial watercourses, except where they exist in a natural watercourse that has been altered by humans (WDCTED 2003).

Watershed – The specific land area that drains into a river system or other body of water (Merz et al. 2008).

Wild - A fish stock that is sustained by natural spawning and rearing in the natural habitat, regardless of parentage (includes native) (WDF et al. 1993).

Wetlands – Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas to mitigate the conversion of wetlands. For identifying and delineating a wetland, local government shall use the Washington State Wetland Identification and Delineation Manual (WDCTED 2003).