# APPENDIX E. DOCUMENTATION USED IN THE EDT MODEL

*This chapter was drafted in 2004 and has not been revised for 2010.*

# APPENDIX E. DOCUMENTATION USED IN THE EDT TREATMENT MODEL

**Tables**

**Figures**

# E.1. Germany, Abernathy, Mill, Elochoman, and Skamokawa Creeks

## E.1.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for Skamokawa Creek, Elochoman River, Mill Creek, Abernathy Creek, and Germany Creek. In this project we rated over 300 reaches with 46 environmental attributes per reach for current conditions and another 45 for historical conditions. Over 27,000 ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute we could find no data within these watersheds. However, Rittmueller (1986) established a relationship between road density and fine sediment in Olympic Peninsula watersheds. We applied this relationship to these watersheds; this is an example of derived information. In some cases such as bed scour we had no data for these basins. However, data is available from the Gobar Creek in the Kalama River and observations have been made in the Wind River. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to estimate bed scour. For rationale behind the ratings see the text below. For specific reach scale information please see the EDT database for the watershed of interest.

Current EDT estimates can be validated when long-term estimates of wild spawners, hatchery spawners, reproductive success of hatchery spawners, and smolts are available. This information in a long enough time series was not available for these watersheds. However, the predicted estimates of steelhead smolt production at equilibrium are reasonably close to estimates from current Washington Department of Fish & Widlife (WDFW) trapping in Mill, Abernathy, and Germany Creeks. Predicted estimates for coho at equilibrium are higher than the observed coho smolt production estimates. However, when current coho harvest rates are considered, the predicted and actual estimates converge. Chum salmon surveys indicate that these fish are at very low abundance levels in these watersheds but current EDT model estimates suggest they may be sustainable at low levels. There was not sufficient information for a comparison for Chinook salmon. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.1.2. Recommendations

Adult chum salmon, Chinook salmon, and steelhead population estimates should continue. However, more emphasis should be placed on determining the number of hatchery spawners and their reproductive success. Adult population estimates for coho salmon should be initiated. Coho, steelhead, and cutthroat smolt population estimates on Mill, Abernathy, and Germany Creeks should continue for another 10 years and be expanded to include chum and Chinook salmon. Adult and juvenile population estimates will allow for more accurate assessments of population status, validation of EDT, and to determine if subbasin restoration actions are effective.

The Cowlitz-Wahkiakum Conservation District data suggests that maximum temperatures in the middle mainstem of these watersheds increase rapidly. A temperature monitoring program should be established to assess maximum water temperatures for each watershed used by anadromous fish and to locate stream reaches where rapid increase in temperature occurs. The factors that cause the increased reach temperatures should be examined and actions to correct the increase in maximum temperature should be developed.

Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.

Sediment estimates were derived information or expanded information from a few observations. A sediment monitoring program should be developed to assess % fines, embeddedness, and turbidity in reaches used by anadromous fish.

Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.

Flow and bed scour are not monitored in these basins and estimates were obtained from derived information and expert opinion. To accurately estimate bed scour and flow, stream gauges should be established or re-established in these watersheds.

WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey only a lower, middle, and high mainstem reach and important representative tributary reaches in each watershed. In addition, glides and pools were distinguished subjectively and not quantitatively. To accurately estimate stream habitat type within the anadromous distribution type a statistically valid sampling design should be developed and applied (Hankin and Reeves 1988 or EMAP). Surveys methodology should differentiate between pools and glides and be repeatable. Currently USFS surveys do not differentiate between pools and glides while TFW surveys allow this distinction.

We used an older EDT guideline to derive an estimate of benthos diversity. Estimates of benthic diversity should be made using a Benthic Index of Biological Integrity (B-IBI).

Not all obstructions were rated using SSHIAP database. Obstruction ratings need to be finalized. Estimates of coho performance may change with undated ratings.

## E.1.3. Attributes

### Hydrologic regime—natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—These watersheds originate from the Willapa Hills. The maximum elevation is approximately 3,000 ft, which is below the elevation of substantial snow accumulation. These elevations are consistent with rainfall-dominated watershed and are classified as such. These watersheds were given an EDT rating of three for the historic and current conditions. The rainfall pattern was used to shape, estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime—regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—These watersheds do not have artificial flow regulation. These watersheds were given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow—change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute rating for watersheds in pristine conditions. Direct measures of inter annual high flow variation are not available for most basins. USFS has conducted watershed analysis in the EF Lewis, NF Lewis, Wind, White Salmon, Washougal, Kalama, Cowlitz, and Cispus Rivers and Rock Creek (USFS 1995a, USFS 1995b, USFS 1996a, USFS 1996b, USFS 2000). Peak flow analysis was conducted using the State of Washington *Standard Methodology for Conducting Watershed Analysis.* The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-1. For watersheds in which the two-year peak flow increases 10% the EDT rating is 2.3. For increases of 5% the EDT rating is 2.13. Based upon the above USFS watershed analyses, when no basin specific data was available for forested watersheds with road systems we assumed a peak flow increase of 10%, and assigned an EDT rating of 2.3.

**Table E7-1. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2-14% |
| East Fork Lewis | 9 | 5-13% |
| Lower Lewis | | 10-12% |
| Rock Creek | | 1-5% |
| Upper Kalama | | 5-10% |
| Cispus | | <10% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow—changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive. Therefore, we rated the template and current conditions the same (EDT rating of 2).

However, water withdrawals may reduce summer flow and the specific withdrawals listed below reduced summer low flow. The Abernathy Technology Center intake removes as much as 70% of flow at summer low flows (pers. com. Abernathy Technology Center). From its withdrawal point to the hatchery outflow, this reach was rated as 3.0. The tide gate and pumping station on Brooks Slough in the Skamokawa subbasin prevents tidal flooding of Brooks 2 reducing estuarine habitat. This reach was rated at 2.5. The Elochoman Hatchery has 3 intakes. Two are located on the mainstem Elochoman in reach 8 and another in Clear Creek in reach 3. Since the Clear Creek intake is not operated in the late summer months and Clear Creek was rated as 2.0. The intakes in Elochoman River affect 20% of reach 8. 1940-71 avg August flow was 43 cfs. The Elochoman Hatchery uses 8-10 cfs or approx. 20-25% of total Elochoman flow in August. Based on this information Elochoman 8 was rated at 2.25. The intake for the water supply for Cathlamet is located at the top end of Elochoman reach 3 and supplies 100% of the town's water. The exact amount of water withdrawn was unavailable, but likely significantly reduces flows in the reach. Elochoman 3 was rated 3. Elochoman 1 & 2 are downstream, but tidal, so the affects of the withdrawal are lessened by tidal influence. These reaches were rated at 2.5 for summer low flow.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow—intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff and hydroelectric development. There are no major metropolitan areas in these watersheds with large areas of impervious surfaces.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow—Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season—a measure of a stream's flashiness during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watershed. Based on USFS watershed analyses we assumed a 10% increase in peak high flows. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in Inter variability in high flows, which translates to an EDT rating for intra-annual flow of 2.3 (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach—Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only—multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width—month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification within the reach affects stream width. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. For reaches above a split (confluence of 2 tributaries), wetted width was calculated by: {(1.5*downstream reach width)*0.5} for even splits. For uneven splits, the multiplier was adjusted to compensate. In a 60:40 split: (1.5*drw)*0.6 and (1.5*drw)*0.4; and for a 70:30 split: (1.25*drw)*0.7 and (1.25*drw)*0.3. These calculations were referred to as the split rule.

For example, in Abernathy Creek mainstem reaches not surveyed were given the same values as surveyed reaches either directly above or below, depending on which had the most similar confinement and gradient. Unnamed tributaries were assigned a width equal to 75% of the value for Weist Creek

(Weist 1); the smallest creek surveyed. Reaches Weist 2-8, Sarah 1, Erick 1, and Slide 1-2 were assigned the same value as Weist 1. Values for upstream reaches of Erick/Midway, Sarah, and Ordway creeks were calculated using the split rule. We used similar methodology in the remaining basins.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width—month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by Steve VanderPloeg (WDFW) in 2003. Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual “wetted width-high” values in reaches where data was available, and a 1.6 multiplier (60%) to expand “wetted width-low” values for reaches without high flow data.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as % gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement—natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003. Confinement ratings were estimated during these surveys (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings.

**Table E7-2. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined & mod. confined | Moderately confined | Equal mod confined & confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement—hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called *headcutting*). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees—consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures and activity) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and WRIA 25 LFA and used professional judgment to assign EDT ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat type

*Definition*—*Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 in diameter), small cobble (2.9 to 5 in diameter), large cobble (5 to 11.9 in diameter), boulder (>11.9 in diameter).

Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower tidal/slough-like reaches of Elochoman & Skamokawa/ Brooks Slough were rated as 100% glides. One small tributary reach in Mill (Trib1232392462718-3) historically supported salmonids, but an impassable, failed culvert has created a lake. This reach is rated at 100% pool.

2002 habitat surveys primarily followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore was estimated but not surveyed. WDFW survey methodology did not appear to work for glides. Therefore, we examined the Wind River data to help differentiate between these two habitat types. Wind River data showed a positive relationship between gradient and/or confinement and riffle. It also showed a negative relationship between pools and gradient and confinement. However, there was no relationship between pools and glides. There was variation between surveyors when the same reach was walked. This may be due to habitat changes but it could also be due to measurement error between surveyors. In general, glides accounted for 30% to 50% of the non-riffle habitat. For this exercise glides were assumed to be 40% of non-riffle habitat. An exception was Elochoman, above the concrete bridge (Hwy. 407 Bridge) we assumed 60% glide and below the salmon hatchery and rock creek 50% glide. Assumptions about glide and pool habitat are most likely to affect coho salmon since they prefer pool habitat during their extended freshwater rearing.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991) presented in the Forest Ecosystem Management document July 1992, page V-23. and applying this to current habitat type composition estimates. On Germany Creek, Elochoman River and Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. We assumed current primary pool habitat has been reduced by 50% on average. Stable historical flows and abundant large woody debris maintained higher levels of spawning gravel than the current condition. Due to increases in primary pools and spawning riffles/tailouts, glides were assumed to be less abundant in the template condition.

In general, we assumed for historical conditions that the percentage of pools was twice the current percentage. We assumed that tail-outs represent 15% of pool habitat. In addition we assumed that primary pool capacity is capped at 45%, with a minimum of 20%. Maximum spawning riffles were capped at 20% and glides were approximately 10% except lower sections of the Elochoman River, which were higher. The net affect was spawning riffles were increased by 33%, and glides reduced appropriately. Rosgen C channels historically had more backwater habitat than they currently do.

In Skamokawa Creek for reaches less than 0.2% slope, the habitat was mainly tidal and/or slough-like. We assumed 100% glides. For reaches between 0.2% and 0.9%, habitat is similar and ratings in Skamokawa were based on LF Skamokawa-1 surveys and Elochoman surveys. For reaches between 1% and 2.5%, habitat is similar and ratings for Skamokawa were based on the averages of McDonald-1 and Wilson-2 and Elochoman ratings were based on the averages of WF Eloch-1, EF Eloch-1, and Eloch-12. For reaches greater than 2.5%, habitat is similar and Elochoman and Skamokawa ratings were based on the averages of NF Eloch-3 and Trib1232562463641 (North Fork Elochoman).

**Table E7-3. Reference reaches used to develop ratings for similar reaches**

| Reference Reaches | Estimated Reaches |
|---|---|
| Eloch-4 | Eloch-3,5&6 |
| Eloch-8 | Eloch-9&10 |
| WF Eloch-1 | WF Eloch-2 |
| Eloch-12 | Eloch-11 |
| EF Eloch-1 | EF Eloch-2,3&5 and Trib1231980463654 |
| NF Eloch-3 | NF Eloch-2&4 |

In Germany Creek, we identified six mainstem areas with similar habitat, gradients, and confinement: Germany 1-3, 5 & 6, 7 & 8, 9 & 10, 11-13, 14 & 15. Surveys from these reaches within these areas were expanded for the entire area. For all small tributaries, we used the survey data from Trib1231282461874-1. In Abernathy Creek, we identified the following areas with similar habitat, gradients, and confinement: Abernathy 1&2, 3-7, 8-10, and 11&12; Cameron 1-4; and Ordway 1-6. For all small tributaries, we used the data from Weist-1.

Since we had no WDFW survey data on habitat types for Mill Cr, we assumed a relationship between Mill Creek and Abernathy/Germany Creeks. For reaches less than 0.2% slope, the habitat was mainly tidal and/or slough-like. Glides were weighted at 100%. For reaches between 0.2% and 0.9%, habitat is similar. Mill-1 inferred from Abernathy-1 minus the current Beaver Ponds. The remaining reaches were applied Germany-4's ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Habitat types—off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. An EDT rating of 0 was assigned to Aa+ and A channels, a rating of 0 to 1 for B channels, while low gradient C channels were assign EDT ratings of 1 to 2 for the current rating and 2 to 3 for the historical rating. Off-channel habitat was significant in Skamokawa Creek and the Elochman River but not other basins.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Obstructions to fish migration

*Definition*—Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*—WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for all barriers. In most cases known fish distribution stopped at all barriers. In some cases where known distribution occurred above barriers passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed for barrier analysis later this month.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. Most watersheds in this unit are forested with limited agriculture and residential use. Water withdrawals were assumed to be minimal in most areas. Reaches with low gradient, unconfined areas (i.e. farmland) and/or reaches with dwellings built next to the stream were given an EDT rating of 0.1 to account for occasional withdrawals. All other reaches were rated at 0

Abernathy Technology Center utilizes a water intake above the facility for hatchery operations. This intake is screened to prevent entrainment. This reach was given an EDT rating of 1.5. No major withdrawals are known to occur in Germany Creek. In Skamokawa Creek the tide gate/pumping station at the downstream end of Brooks Slough is designed to prevent flooding of the Columbian Whitetail Deer Refuge. Water is pumped out of reach into Brooks Slough-1, reducing estuarine habitat. Pumps are believed to be screened; given an EDT rating of 1.5. The Elochoman Salmon Hatchery has a total of 3 intakes. Two are on the mainstem Elochoman (Elochoman-8): (1) upstream 0.4 miles, and (2) at the hatchery swim-in pond (upper pond). The third is on Clear Creek in Clear-3 just across Elochoman Valley

Rd. All are screened and operate at different levels throughout the year depending on water needs. Elochoman-8 was given an EDT rating of 2. Clear-3 was rated at 1.5. The water supply for Cathlamet is just below the concrete bridge (Hwy 407) in Elochoman-3 (top of reach) and supplies 100% of the town's water. The intake is subterranean 2-4 ft below the riverbed. Actual amount of water withdrawn was unavailable. Elochoman-3 was given a rating of 2. Beaver Creek Hatchery is no longer in operation and the intake is shut down.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 in diameter), small cobble (2.9 to 5 in diameter), large cobble (5 to 11.9 in diameter), boulder (>11.9 in diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table relates bed scour to confinement, wetted width (high flow), and gradient and assumes scour increases as gradient and confinement increase. In tidal reaches such as Elochoman-1 and Skamokawa –1 where reach was historically estuarine/wetland bed scour was rated as 0. In tidal reaches such as Germany-1, where scour likely occurred during low tides and high flow events, the pristine look-up table ratings were reduced by ½.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour was increased as follows: Peak flow increased from 2.0 to 2.3 from the template to the patient and we assumed this had a similar effects on bed scour; as hydro-confinement ratings increase 1 point we increased bed scour ratings by 0.1. In tidal reaches such as Elochoman-1 and Skamokawa –1 where reach is currently slough-like (mud bottom) bed scour was rated as 0. In tidal reaches such as Germany-1, where scour likely occurs during low tides and high flow events, the current look-up table ratings (plus added tenths) were reduced by half.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—These watersheds are rainfall dominated. Anchor ice and icing events do not occur. EDT ratings of 0 were assigned to all reaches in the historical and current condition.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 1.0. Riparian with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2 residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of two or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating.

Key reaches in the Abernathy watershed were rated. Abernathy 1 has 10% hydro-confinement, and a mix of alder and conifers. Alder and immature stands give a score of 1.5 and hydro-confinement led to a score of 0.5. The total riparian score was 2 = (0.5 + 1.5). Based on habitat survey data from Cowlitz-Wahkiakum Conservation District, Ordway-2 is set at an EDT rating of 1 because the riparian area has no roads, 90% conifers within the riparian zone, an average DBH of 14 ines, and average tree height of 80 ft. Abernathy-4 was set at a rating of 2 because the riparian zone lacks trees and where trees are present, they are mid-aged alder. In addition, this reach has a hydro-confinement rating of 1 indicating the road disrupted floodplain connectivity. All riparian ratings in Abernathy Creek will range from 1 to 2.

On Abernathy Creek, the Cowlitz-Wahkiakum Conservation District surveyed all mainstem reaches. For those tributaries with no data we expanded ratings for the following: everything above Cameron-1 we used ratings from Cameron-1, everything above Weist-4 we used ratings from Weist-4, everything above Erik-3.

Key reaches to set riparian function ratings on Germany Creek were Germany-12 and Germany-7, which receive a 2 and a 1, respectively. Other reaches were referenced to these reaches. On Germany Creek, the Cowlitz-Wahkiakum Conservation District surveyed all mainstem reaches. Only 7 tributary reaches were surveyed, with a mean rating of 2. Therefore unsurveyed tributaries were assigned a rating of 2.

Skamokawa 1-3 are rated at 4 due to diking of both banks and lack of riparian vegetation. From Skamokawa 4 to 5, reaches are rated as a 3 due to lack of riparian vegetation and bank erosion. McDonald Creek was rated as a 1 due to presence of old-growth spruce and maple, lack of roads (no hydro-confinement), and lesser bank erosion. Skamokawa 6 was rated as a 2, similar to Abernathy-4.

**Table E7-4. Expanded reaches for riparian ratings used for Skamokawa Creek**

| Measured Reaches | Reaches expanded into |
|---|---|
| Beaver Cr-2 | Trib1233963462747, Alger-3&4, Risk 3&4 |
| Wilson-6 | Trib1234882462959-1&2, Trib1233243462950-1 thru 3, and Trib1233218462941 |
| Cadman-3 | Cadman-4, Kelly-1 thru 3, Trib1234786463114, and Trib1234799463228 |
| Trib1233641463035-1 | Trib1233641463035-3 |
| Falk-3 | Falk-1&2 |
| Pollard-2 | Pollard-3 |
| Skamokawa-5 | Trib1234475463088 |
| LF Skam-2 | Trib1234547463284-1&2, Trib1234642463345-1,2&4 and Trib1234695463368 |
| Quarry-1 | Quarry-2&3 |
| McDonald-3 | McDonald-4&5, and Trib1233973463412-1&2 |
| Standard-2 | Standard-3 |

Elochoman 4 received a rating of 1.5 for its good floodplain connectivity, large mature alders and maples, but lack of conifers. The EF Elochoman received a similar rating because there are no hydromodifications, and the reach has good shade because it is forested. However, the lack of conifers, bank stability and large woody debris recruitment cause a rating of 1.5. The mainstem Elochoman downstream of EF Elochoman was given a rating of 2 for its lack of abundant conifers, and the presence of stream-adjacent road (hydro-confinement). Eloch-12 was given a rating of 2 due to mature mixed stand present on only one side and an old road and fields on right bank, causing a loss of bank stability and shade. The WF Elochoman was given a 1.5 due to lack of conifers, resulting in loss of stability and shade. Although there is more LWD on the WF than EF, it's hard to differentiate the two. NF Elochoman received a 2, mainly due to the presence of the road, which decreases shade trees, and sporadic rip-rapping. Elochoman-5 was set at a rating of 2 due to the hydro-confinement rating of 1 because of riprap at hatchery. The right hand bank below Beaver Creek is devoid of vegetation, the left bank has combination of alder and maple with few conifers.

**Table E7-5. Expanded reaches for riparian ratings used for Elochoman River**

| Measured Reaches | Reaches expanded into |
|---|---|
| Trib1233032462252-3 | Trib1233032462252-5 |
| Beaver-6 | Beaver-8 |
| Average rating for Beaver & Duck Cr = 3 | Clear-1,3&5, Rock-1&3, Trib1232859462932, and Trib1233126462580 |
| Average rating for WF & EF Elochoman, and Otter Cr =4 | Otter-2,3&4, Tribs:1231932463600, 1231980463654, 1231991463706, 1232156463572, 1232189463844, 1232307463467, 1232312463788, 1232328463648, 1232792463272, 1232902463299, 1233089463480-2, 1233115463513 |

There was limited data for the Mill Creek basin. Due to lack of reach specific knowledge and data, and based on recent logging practices within the basin, all reaches were rated at a 1.5, except those with a hydro-confinement rating of 1, which were rated at a 2.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to large pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—LWD density was calculated from the Cowlitz-Wahkiakum County Conservation District surveys where density of LWD equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. When the Cowlitz-Wahkiakum County Conservation District surveys not available WDFW habitat survey data (VanderPloeg 2003) was used and extrapolated to other reaches. Since WDFW measured large LWD (> 0.5 meters in diameter), we increased the associated EDT rating by 1 to account for small diameter pieces (.1 to .5 meter), which are typically retained in debris jams.

On Germany Creek, the Cowlitz-Wahkiakum Conservation District surveyed all mainstem reaches. Only 7 tributary reaches were surveyed, with a mean rating of 2. Therefore unsurveyed tributaries were assigned a rating of 2. On Mill Creek, the Cowlitz-Wahkiakum Conservation District surveyed reaches Mill-1 thru Mill-7A. The average rating was 3, which was applied to the remaining reaches.

On Abernathy Creek, the Cowlitz-Wahkiakum Conservation District surveyed all mainstem reaches. For those tributaries with no data we expanded ratings for the following: everything above Cameron-1 we used ratings from Cameron-1, everything above Weist-4 we used ratings from Weist-4, everything above Erik-3 and Midway we used ratings from Erick-3, everything above Ordway-3 & 5 we used ratings from Ordway-3.

**Table E7-6. Expanded reaches for wood ratings used for Skamokawa Creek**

| Measured Reaches | Reaches expanded into |
|---|---|
| Beaver Cr-2 | Trib1233963462747, Alger-3&4, Risk 3&4 |
| Wilson-6 | Trib1234882462959-1&2, Trib1233243462950-1 thru 3, and Trib1233218462941 |
| Cadman-3 | Cadman-4, Kelly-1 thru 3, Trib1234786463114, and Trib1234799463228 |
| Trib1233641463035-1 | Trib1233641463035-3 |
| Falk-3 | Falk-1&2 |
| Pollard-2 | Pollard-3 |
| Skamokawa-5 | Trib1234475463088 |
| LF Skam-2 | Trib1234547463284-1&2, Trib1234642463345-1,2&4 and Trib1234695463368 |
| Quarry-1 | Quarry-2&3 |
| McDonald-3 | McDonald-4&5, and Trib1233973463412-1&2 |
| Standard-2 | Standard-3 |

**Table E7-7. Expanded reaches for wood ratings used for Elochoman River**

| Measured Reaches | Reaches expanded into |
|---|---|
| Trib1233032462252-3 | Trib1233032462252-5 |
| Beaver-6 | Beaver-8 |
| Average rating for Beaver & Duck Cr = 3 | Clear-1,3&5, Rock-1&3, Trib1232859462932, and Trib1233126462580 |
| Average rating for WF & EF Eloch, and Otter Cr =4 | Otter-2,3&4, Tribs:1231932463600, 1231980463654, 1231991463706, 1232156463572, 1232189463844, 1232307463467, 1232312463788, 1232328463648, 1232792463272, 1232902463299, 1233089463480-2, 1233115463513 |

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fine sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of fine sediment here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992) and EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

Rittmueller (1986) found that as road density increased by 1 km/sq.km, fine sediment levels increased by 4.3%. To rate % fines in the current condition, a scale was developed relating road density to % fines. The majority of Rittmueller's data was on streams with gradients of 0.5% to 1.5%. As gradients increased % fines would decreased. For gradients between 2% and 5%, we assumed fines were reduced by 25% and for gradients above 5% we assumed fines decrease by 50%.

Tidal reaches with lower gradients were given an EDT rating of 4. Slough-like reaches above tidal reaches or tidal reaches with increased flow during outgoing tide (i.e. Germany Ck.) were rated as follows: rating from road density scale + 1.

For Germany, Abernathy, Mill, Skamokawa, Elochoman, and North Elochoman the road densities (mi/mi^2) were 5.8, 4.2, 4, 4, and 2.5, respectively (Lunetta et al., 1997 and Eric Doyle, URS Pers Com).

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have less than 10% embeddedness. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

Rittmueller (1986) found that as road density increased by 1 km/sq.km, fine sediment levels increased by 4.3%. To rate embeddedness for the current condition, we assumed that the percent embeddness was directly related to percentage of fines in spawning gravel. A scale was then developed relating road density to percent embeddedness. The majority of Rittmueller's data was on streams with gradients of 0.5% to 1.5%. As gradients increased percent embeddedness would decrease. For gradients between 2% and 5%, we assumed embeddedness was reduced by 25% and for gradients above 5% we assumed embeddedness decreased by 50%.

Tidal reaches with lower gradients were given an EDT rating of 3. Slough-like reaches above tidal reaches or tidal reaches with increased flow during outgoing tide (i.e. Germany Ck.) were rated as follows: rating from road density scale + 1.

For Germany, Abernathy, Mill, Skamokawa, Elochoman, and North Elochoman the road densities ($mi/mi^2$) were 5.8, 4.2, 4, 4, and 2.5, respectively (Lunetta et al 1997 and Eric Doyle URS Pers Com).

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. An EDT rating of 0 was assigned to all reaches.

Suspended sediment, turbidity, and flow data does not exist or is limited for the Skamokawa, Abernathy, Mill, Germany and Coal Creek watersheds. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978.] Maximum turbidity was recorded at 65 JTU on 12/26/1972 at a flow of 3700 cfs. Assuming a 1:1 conversion this equals 65 NTU. Assuming a 1:4 conversion this equals 260 NTU. Excluding the maximum turbidity on 12/26/72, turbidity ranged from 2.7 to 60 JTU/NTU (depending on the conversion used) at flows greater than 1000 cfs.

To try and understand the duration of high flow and turbidity events, the 1940 to 1971 Elochoman River discharge dataset was queried to determine the average number of days/year, in which discharge exceeded 1000, 2000, 2500, 3000, and 3700 cfs. Results were: 29, 6, 3, 2, and 1 days/year, respectively. The average monthly flow for this time period was 794 cfs for December and 783 cfs for January. The turbidity to suspended sediment (SS) relationship for Puget lowlands provided in the EDT guidelines was used to equate turbidity to SS. This relationship shows that at approximately 100 NTU suspended sediment equals approximately 500 mg/l. 260 NTU would equal approximately 1800 mg/l SS.

From these results we determined that flows greater than 2000 cfs were infrequent. At flows less than 2000 cfs, turbidity was found to be less than 60 NTU. The infrequent events greater than 2000 cfs may produce SS readings greater than 1000 mg/l for short durations. An EDT rating of 1.6 was determined to best fit these results. The turbidity ratings were taken in the lower Elochoman watershed below agriculture lands, where sediment inputs can be high. Above Beaver Creek, the watershed was given a rating of 1.

Based on this information the EDT rating of 1.0 was used for entire Abernathy, Germany, and Mill Creek watersheds. The lower Skamokawa (Wilson Creek down) and Brooks Slough (1&2) were rated at 1.6, which is similar to the lower Elochoman. All other reaches in Skamokawa were rated at 1.0.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

## Temperature—daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—The Cowlitz-Wahkiakum County Conservation District placed temperature loggers in various locations within Elochoman, Grays, Skamokawa, Abernathy, Mill, Germany, and Coal creek watersheds during the summer of 2002. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern "TmpMonMax Rainfall" (9) for the rainfall dominated watersheds in SW Washington. Elochoman River and Clear Creek temperatures are taken daily at the Elochoman Hatchery from intakes for each stream. The 12-year average from the Elochoman and 4-year average from Clear Creek for temperatures on these streams was compared to the 2002 temperatures. It was found that August 2002 temperatures were very near average. It was assumed temperatures recorded in other watersheds during 2002 were also near average.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers—ratings from reaches with temperature loggers were feathered for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Cowlitz at 12-19 C, the Lewis at 15-19 C, the Hood/Wind at 7-20 C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures.

Historical maximum stream temperature data was limited in the Lower Columbia River domain. The only historical temperatures data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of a spot measurement and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate maximum temperature we had to look at the effect of human activities that effect thermal energy transfer to the stream. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated bankfull width and assumed that trees in the riparian zone were present at the edge of bankfull delineation in the smallest tributaries but averaged 5 meters from the bankfull with class 3 streams . Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these tress are estimated to be between 40—50 meters for cedar to 60 to 80 meters for Douglas fir (Pojar and MacKinnon 1994). USFS uses 51 meters as the average tree height in the riparian within the western hemlock zone (Brian Bair, USFS personal communication). The combination of the height of the bank and average effective tree height was 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade we used the relationship between forest angle and percentage of shade (Doughty et al 1991, page 35 Table 5.1). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for historical water temperature.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were slightly lower (70% to 80%). These differences are not unexpected, since the Doughty et al. (1991) developed their shade and forest relationship for larger stream (class 1-3) and it does not account for the increased shade provided by tree limbs in small streams.

*Level of Proof—A* combination of derived information and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature—daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Elochoman Hatchery monitors temperature in the Elochoman River and Clear Creek. The 12-year average for Elochoman and the 4 year average for Clear Creek for temperatures on these streams was compared to the 2002 temperatures from the Cowlitz/Wahkiakum County Conservation District temperature loggers in Elochoman, Grays, Skamokawa, Abernathy, Mill, Germany, and Coal creek watersheds during 2002. It was found that January 2002 temperatures were average. This data was plugged into the EDT temperature calculator (MS Access) provided by Mobrand, Inc. to produce EDT ratings. These data indicate that the minimum water temperature rarely dropped below 4 degrees. The historic minimum temperature was assumed to be the same as current minimum temperatures—with the coldest day >4 deg C.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Temperature—spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Elochoman, Washougal, Wind, Kalama, and Lewis Rivers using the formula: Alkalinity =0.421*Conductivity—2.31 from Ptolemy (1993). Alkalinity values for the five aforementioned rivers were averaged resulting in 17.8mg/l or an EDT rating of 1.8. This value was used for Abernathy, Germany, Mill and Skamokawa Creeks. For the

Elochoman River alkalinity was calculated as 26.7 mg/l or an EDT rating of 2.1. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All reaches in these watersheds were assumed to be unimpaired for dissolved oxygen, except for the lower slough reaches of Elochoman and Skamokawa where water temperatures are consistently elevated in July/August.

WRIA 25 LFA reports Skamokawa is 303 D listed for temperature, dissolved oxygen, and turbidity (Wade 2002). A 1975 fish kill prompted a water assessment. “Aerating falls and riffles as well as attached aquatic plants are almost nonexistent in the lower reaches of the creek due to the silty bottom conditions which prevail. During the early morning hours when the dissolved oxygen concentration reaches a minimum, the added burden of several hundred fish moving upstream to spawn probably caused critical dissolved oxygen concentrations to be reached,” (Tracy 1975 cited in Norton 1981). Based on this information, Skamokawa 1-3, WF Skamokawa 1, Brooks 1-2, Alger 1A, and Risk 1 were given an EDT rating of 1.0. All other reaches in the basin are assumed to be unimpaired and were rated at 0.

WRIA 25 LFA reports Elochoman is 303 D listed for temperature (Wade 2002). There is a correlation between water temperatures and dissolved oxygen. Elochoman 1-2, and Nelson 1-2 are slough-like and lack aerating falls and riffles and aquatic plants. Elochoman reaches from Beaver Creek Hatchery to tidal (3-5) are wide with little shading from riparian cover. Warm August temperatures, low summer flows, and nutrient enrichment in these areas likely reduce DO levels. Elochoman 1-5 and Nelson 1-2 were given an EDT rating of 1.0. All other reaches were rated at 0.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals—in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because, of the lack of data.

### Metals/Pollutants—in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Miscellaneous toxic pollutants—water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the pristine state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off.

Except for Elochoman and Skamokawa valleys, nutrient enrichment throughout these watersheds was assumed to be non-existent or at low levels. Fertilizing by timber companies is very minimal—less than 250 acres @ 435 lbs. fertilizer/acre in 2002. (pers. com. Mebust, Cathlamet Timber Company).

A small amount of nutrient enrichment may be occurring below Abernathy Technology Center from hatchery operations there. The reach directly below the hatchery was given an EDT rating of 1. Effects were assumed to be diluted by incoming tributaries. The EDT rating was reduced to 0.75 below Slide Creek and 0.5 below Cameron Creek.

In Germany Creek a small amount of nutrient enrichment may be occurring in reaches 4-6. This area is less confined and the river valley bottom is used for agriculture by private landowners—mostly grazing of cattle and other livestock as well as growing hay. Reach 5 is probably the most heavily impacted, and was given an EDT rating of 0.8. Reaches 1-4 (downstream) were diluted only slightly (0.5) as there are no major tributaries entering in these reaches, only small feeder streams and seepage. Reach 6 was given a rating of 0.5.

The lower portion of Mill-3 has a few homes along the creek, but aerial photos indicate agriculture use next to the stream is minimial—this reach was rated at 0. South Fork Mill-1 is low gradient/unconfined and has some small scale agriculture and potential for septic inputs from homes in the reach. This reach was given an EDT rating of 0.5. Mill 1 and 2 (below confluence with SF-1) likely dilute the effects of nutrient enrichment and were given a rating of 0.25.

The lower reaches of the Skamokawa watershed (West, Middle, East Valley & lower Skamokawa) have a significant amount of agriculture (mostly grazing of livestock), and the potential for fertilizing. The valleys are rural, but with a significant amount of homes, with the potential for septic input into the watershed. A 1975 WQ assessment (prompted by a fish kill) found that fecal coliform was above state standards and probably caused by human and animal sources (Wade 2002). Lower valley reaches were rated between 1 and 1.5. Upper watershed reaches were rated at 0.

The lower reaches of the Elochoman watershed (Elochoman 1-6 and Nelson 1-2) have a significant amount of agriculture (livestock) and the potential for fertilizing and septic inputs from homes along the stream. The Elochoman Salmon Hatchery outflow channel is in reach Elochoman 7. The hatchery may produce some low level nutrient enrichment from hatchery operations. Dilution by downstream tributaries is negated by agricultural/septic inputs in downstream reaches. Eloch 1-7 and Nelson 1-2 were given an EDT rating of 1.5. All other reaches were rated at 0.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: 1) smolt trapping activities on Abernathy, Germany, and Mill creeks (pers. com. Hanratty, WDFW), 2) electro-shocking in 2002 by USFWS in Abernathy Creek (pers. com. Zydlewski, USFWS), 3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), 4) WDFW snorkel surveys on the Elochoman River (pers. com. Byrne, WDFW), 5) species present in Hardy Slough (pers. com. Coley, USFWS), 6) Reimers and Bond (1967), and 7) McPheil (1967).

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Lower Elochoman River and Skamokawa Creek/Brooks Slough (slough-like) likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coastrange, reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this - it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW). The majority of these species were dropped out at Wilson Creek and WF Skamokawa 2 and at the end of the tidal zone (Elochoman-2 and Nelson-2). E. banded killifish was presumed to be present up to the Elochoman Hatchery.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

The only non-native species documented in Abernathy Creek is the eastern banded killifish captured in smolt trap (pers. com. Hanratty, WDFW). In Abernathy Creek, the distribution most likely stops at or near Slide Creek. In Germany and Mill, we assume this species drops out in the in Germany 6 and Mill 3, receptively. The eastern banded killifish, reported from Elochoman River snorkel surveys (pers. com. Byrne, WDFW), was presumed to be present up to the Elochoman Hatchery.

The tidal reaches Abernathy 1, Germany 1, and Mill 1 have potential for more exotics from the Columbia River. Non-native species in upper Germany Creek, upper Mill Creek, and Abernathy Creek above the falls and in upper tributaries, have not been documented by electroshocking in these reaches (pers. com. Hallock, WDFW & Zydlewski, USFWS).

The lower reaches of Skamokawa Creek and Elochoman River likely have many non-native fish from the Lower Columbia River. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. The majority of these species were dropped out on Skamokawa Creek at Wilson Creek and WF Skamokawa 2, and on the Elochoman River at Elochoman 2 and Nelson 2.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. Drainage here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW).

Annual plants of Chinook and steelhead were discontinued in Abernathy Creek in 1999. Steelhead plants resumed in 2003. Cutthroat were released in 1995-97 and 1999. An EDT rating of 2 was given from Abernathy Falls downstream (mainstem only). In Germany Creek, annual plants of hatchery steelhead in the watershed were discontinued after 1999. Cutthroat releases were terminated after 1996. Releases of coho and steelhead in Mill Creek were discontinued in 1996 and 1997, respectively. Annual plants of hatchery steelhead in the Skamokawa Creek watershed occurred through 1997. Another release occurred in 2000. Since the hatchery programs were discontinued in Mill, Germany, and Skamokawa Creeks, an EDT rating of 0 was given to all reaches within these watersheds.

Annual releases of early/late coho, fall Chinook, summer/winter steelhead occur in the Elochoman River (pers. com. D. Miller, WDFW). Sea-run Cutthroat trout were released from 1994-97. An EDT rating of 3 was given to reaches downstream of the hatchery including Elochoman 1-7 and Nelson 1-2. Beaver Creek Hatchery is closed and no longer releases fish.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*—For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. Hatcheries are currently in operation on the Elochoman River and Abernathy creek. Hatchery personnel were asked about known viral incidents among hatchery releases. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency.

In Abernathy Creek annual plants of Chinook and steelhead were discontinued in 2000. Steelhead plants resumed in 2003. Cutthroat were released in 1995-97 and 1999 and have been discontinued. An EDT rating of 2 was given from Abernathy Falls downstream (mainstem only). All other reaches were rated at 0. Annual plants of hatchery steelhead in the Germany creek watershed were discontinued in 2000. Cutthroat were released in 1996. An EDT rating of 1 was given to reaches Germany 1-6, where planted salmonids were released. All other reaches were rated at 0. A release of coho was made in 1996 and a release of steelhead in 1997 into Mill Creek. Plants have been discontinued. Mill 1,2, & 3 were given an EDT rating of 1. All other reaches were rated at 0.

Annual plants of hatchery steelhead in the Skamokawa Creek watershed occurred through 1997 with the final release in 2000. An EDT rating of 1was given to reaches Skamokawa 1-6. All other reaches were rated at 0. Elochoman Hatchery annually releases early/late coho, fall Chinook, summer/winter steelhead (pers com D. Miller, WDFW). Sea-run cutthroat releases were discontinued in the late 1990's. The hatchery is located in reaches 7 and 8 (intake & upper ponds in 8 and outflow & lower ponds in 7) and these reaches were rated as 3. Elochoman 1-6 and Nelson 1-2 were rated at 2. All other reaches were rated at 0.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT ratings of 4 was given to reaches with extensive road/boat access and high recreational use (i.e. Elochoman between upper hatchery and Risk Rd. bridge due to extensive road access and high recreational use and lower Kalama River); 3 was given to areas with road/boat access and proximity to population center and moderate use (i.e. Abernathy 1&2 road/boat access and moderate recreational use); 2 was given to reaches with multiple access points (or road parallels reach) through public lands or unrestricted access through private lands (i.e. above salmon hatchery on Elochoman and Abernathy); 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands (i.e. Skamokawa Middle Valley—private farm lands with road access, but limited public access); 0 was given to reaches with no roads and that are far from population centers.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions.

The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species is unknown in these watersheds.

For Abernathy, Germany, and Mill Creeks, no known populations of non-native piscivorous fish have been documented from smolt traps and electroshocking (pers. com. Hanratty, WDFW, Hallock, WDFW, & Zydlewski, USFWS). Current predation levels were assumed to be the same as the template. The tidal reaches (Ab-1, Gem-1, Mill-1) were assigned an EDT rating of 2.5 as non-native piscivorous fish species known to exist in the Lower Columbia River may utilize this reach.

Skamokawa Creek from the mouth up to Wilson Creek (reaches 1-3), Brooks Slough (1-2) and West Valley Creek (1-2) are tidal and/or slough-like. The Elochoman River from the mouth up to the Foster Rd. bridge (reaches 1-2), and Nelson Creek 1-2 are also tidal and/or slough-like. Populations of non-native piscivorous fish from the Lower Columbia River are known to exist in this type of habitat although the exact number of species and their distribution have not been well documented. Skamokawa, Brooks Slough, and West Valley Creek reaches were given an EDT rating of 2.5. In addition, the WDFW Elochoman Salmon Hatchery releases hatchery early & late coho, fall Chinook, and winter &

summer steelhead. Predation is likely increased on native fish in all mainstem reaches below the hatchery. Eloch 1-2 and Nelson 1-2 were given an EDT rating of 3. Eloch 3-7 were given a rating of 2.5. In all other reaches, we assumed current predation levels were the same as the template.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches).

In Abernathy, Germany, Mill, Elochoman, and Skamokawa all template carcass information was determined by the above rules. Historically, only winter steelhead passed above Abernathy Falls. Reaches above the falls were given an EDT rating of 4 for low carcass abundance. Below the falls, carcasses per mile was determined by the above rules. In Skamokawa Creek—McDonald 1, Standard 1 and Quarry 1 are listed as having historic chum distribution, but due to their distance from the mouth and small size these tributaries were given an EDT rating of 3 (instead of 0).

An estimate of the current number of salmon carcasses per mile was derived from natural spawn escapement estimates for salmonids in each basin, EDT reach length data, and fish distribution data. Natural spawn escapement estimates for fall Chinook and chum are available from WDFW stream surveys. For Chinook, the ten-year average (1992-2001) was used. For chum, 2001 escapement estimates were used. Natural spawn escapement estimates are not available for coho from stream surveys.

Coho estimates on Germany, Mill, and Abernathy creeks were back-calculated from 2001 & 2002 smolt production estimates (pers. com. Hanratty, WDFW). Calculations were made assuming a 4% smolt to adult survival rate, and adding a coho jack estimate calculated as 10% of the total adult run (pers. com. Seiler, WDFW). Coho estimates on Elochoman were derived from 2001 stream surveys below the hatchery, hatchery escapement numbers from 1982-2001, counts of coho placed upstream of the hatchery barrier, and estimates of barrier efficiency. Coho escapements were not available for Skamokawa Creek. Skamokawa does not have a hatchery or hatchery plants of coho. Abernathy coho carcass densities were used as a surrogate for Skamokawa Creek.

During template development, EDT reaches were delineated by Ned Pittman (WDFW) according to current/potential fish distribution. Using potential fish distribution, EDT reach lengths were summed to develop the total number of miles of available habitat for each species. The natural spawn escapement estimate was divided by the corresponding number of miles of habitat to generate the average number of carcasses per mile for each species. These values were summed according to the species present within each reach to develop the total number of carcasses per mile within the reach.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—No direct measures of benthos diversity were available for these watersheds. We assigned an EDT rating of 0 and assumed that in the historic condition macroinvertebrate populations were healthy, diverse, and productive and in the natural/pristine state.

Nutrient enrichment levels and mean August temperatures were applied to the *lookup table* in the September 2000 EDT Guidelines to generate an EDT rating. This rating is most likely biased low (indicating macroinvertebrates are better than they actually are) because the look-up table does not take into account fine sediment loads, riparian function, and toxic chemicals. For the majority of reaches, nutrient enhancement was minimal and average August water temperatures fell between 12 and 20 deg. C producing an EDT rating of 0.

For reaches below Abernathy Technology Center where nutrient enhancement may be increased due to hatchery operation an EDT ratings were as follows: 1 below Tech center (Abernathy-4), 0.5 in Abernathy-3, and 0.25 in Abernathy1 & 2. In Germany Creek reaches below the canyon where nutrient enrichment may be increased due to agriculture, an EDT rating of 0.8 was assigned in Germany-5, and 0.5 in reaches 1-4 and 6. SF Mill –1 potentially has some nutrient enrichment and was given a rating of 0.5. Mill 1&2 were rated at 0.25. All other reaches were rated at 0.

West, Middle, & East valley and lower Skamokawa, plus Brooks Slough have nutrient enrichment values of 1 to 1.5. EDT ratings for macroinvertebrates were the same (from look up table), except for Skamokawa 1-3, Brooks 1-2, Risk 1, and Alger 1A. These reaches are slough-like and likely have increased fine sediment. Look up table values in these reaches were increased by 0.5.

Elochoman 1-7 and Nelson 1-2 have nutrient enrichment values of 1.5. EDT ratings for macroinvertebrates were the same (from look up table), except Elochoman 1-2 and Nelson 1-2. These reaches are slough-like and likely have increased fine sediment. Look up table values were increased by 0.5.

# E.2. Coweeman River

## E.2.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treatment Model (EDT) for the Coweeman River. In this project we rated over 60 reaches with 46 environmental attributes per reach for current conditions and another 46 for historical conditions. Over 2,700 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact, less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data for most reaches. However, data is available from Gobar Creek (a Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.2.2. Recommendations

1. Adult Chinook salmon, and steelhead population estimates should continue for the basin. Currently, winter steelhead estimates are based upon redd count expansion, while Chinook estimates have been generated from index counts and peak count expansion. There are no hatcheries operating in the Coweeman Basin, and the only hatchery plants consist of summer steelhead. The NMFS identified Coweeman Tule fall Chinook salmon as an indicator stock to determine recovery exploitation rates (RER) for all naturally produced LCR Tules that are consistent with the recovery of tule fall Chinook. Chum and coho salmon counts are periodic and not population estimates. Funding should be secured to develop accurate and precise adult estimates for chum, fall Chinook and coho salmon and winter steelhead. Smolt populations are currently not monitored in the basin. Funding should be secured to generate smolt population estimates for the above species as well. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective.

2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating, as would field surveys.

3. Empirical sediment data was not available for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.

4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Flow monitoring in the mainstem Coweeman River was discontinued in the early 1980s. Flow monitoring should be resumed. Bed scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. USFS and USGS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey only a few “representative” mainstem and tributary reaches. In addition, glides and pools were distinguished subjectively and not quantitatively. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves 1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. A combination of Ecology and OSU estimates of Benthic Index of Biological Integrity (B-IBI) collected in the Wind and Cowlitz River basins were used to develop EDT ratings. These estimates should be completed in this and other SW Washington watersheds.
8. Obstructions were not rated and passage was assumed to be 100%. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. These ratings should be updated using SSHIAP database.

## E.2.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale:* This watershed originates from foothills below 3000 feet (Wade 2000). Washboard falls is likely the uppermost barrier to anadromous fish on the mainstem Coweeman, and is at an elevation of approximately 1150 feet. Upper elevations of the Coweeman watershed likely experience rain-on-snow events. These events influence lower mainstem reaches, but effects are likely masked by tributary flow inputs as one progresses downstream. The Integrated Watershed Assessment (IWA) completed for the Lower Columbia Fish Recovery Board (LCFRB) examined the current condition of key watershed processes by Hydrologic Unit Code (HUC) (LCFRB 2003). IWA results present the percent rain-on-snow area by HUC. EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries (LCFRB 2003). Rain-on-snow percentages range from 0 to 61% for HUCS with associated EDT reaches (Table E7-8). As a general rule, reaches with percentages >45% were given an EDT rating of two (rain-on-snow transitional), and reaches with <45% were given an EDT rating of three (rainfall dominated). Exceptions to this rule are as follows: (1) EDT reaches Coweeman 19 & 20 were rated as rain-on-snow transitional due to influence from upstream reaches (below Coweeman 19 rainfall dominated tributaries likely begin to dilute rain-on snow effects), and (2) all of Mulholland Creek was rated rain-on-snow transitional. Natural flow regime ratings were used for both historical and current conditions. Each reaches natural flow regime was used to assign shape patterns when rating other EDT attributes.

**Table E7-8. % Rain-on-Snow Area for HUCs with associated EDT reaches.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC % Rain on Snow Area |
|---|---|---|
| 17080005080301 | C7(.5), C8, C9, C10, C11, C12, LB2, LB3, RB3, Jim Watson Cr, Sam Smith Cr | 0 |
| 17080005080302 | M1, M2, RB6, LB5 | 0 |
| 17080005080303 | C13, C14, C15, RB4, LB4 | 6 |
| 17080005080304 | B1, B2, B3, LB6, Little Baird Cr | 56 |
| 17080005080305 | RB5, C21, C22 | 61 |
| 17080005080306 | M3, M4, RB7 | 45 |
| 17080005080307 | C16, C17, C18, C19, C20, Nineteen Cr, Skipper Cr, Brown Cr, O'neil Cr, Martin Cr | 27 |
| 17080005080401 | C5, C6, C7(.5), RB2, Canyon 2, Nye Cr | 0 |
| 17080005080402 | C2(.5), C3, LB1 | 0 |
| 17080005080403 | C4, RB1, Canyon 1, Turner Cr | 0 |
| 17080005080404 | NF Goble Cr | 22 |
| 17080005080405 | G1, G2, G3, G4 | 13 |
| 17080005080407 | C1 tidal, C2(.5) | 0 |

Actual flow data is limited for the Coweeman watershed. One gauge was operated by USGS near Kelso, WA from 1950-1982 (USGS 2004). An examination of mean monthly flow data from this gauge supports the above ratings for the lower watershed. Mean monthly flow data was plotted and compared to EDT flow patterns for a rainfall dominated watershed and a rain-on-snow transitional watershed. Gauge data showed a clear rainfall dominated pattern with high winter flows decreasing steadily through the spring into summer.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watershed does not have artificial flow regulation, and was given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Direct measures of interannual high flow variation are not available for most basins. USFS has conducted watershed analysis in the EF Lewis, NF Lewis, Wind, White Salmon, Washougal, Kalama, Cowlitz, and Cispus Rivers and Rock Creek (USFS 1995a, USFS 1995b, USFS 1996a, USFS 1996b, USFS 2000). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-9. For watersheds in which the two-year peak flow increases 10% the EDT rating is 2.25. For increases of 20% the EDT rating is 2.5. Data for the Upper Kalama Basin indicated an increase in peak flow of 5 to >10% (Table E7-9). A Q2yr analysis of peak flow data (using EDT manual protocol) for USGS gauge data on the Kalama River below the lower falls (1934-1977) indicated a peak flow increase of 17% (EDT rating ~ 2.4). Upper and lower basin ratings were averaged and an EDT rating of 2.3 was used on the Kalama. The flow-data time series on the Coweeman River was not long enough to conduct a Q2yr analysis. The Kalama was used as a surrogate and all Coweeman reaches were given an EDT rating of 2.3.

**Table E7-9. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10-12% |
| Rock Cr | | 1-5% |
| Upper Kalama | | 5- >10% |
| Cispus | | <10% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Research on the effects of land use practices on summer low flow is inconclusive. Therefore, template and current conditions were rated the same (EDT rating of 2), except where noted.

The LCFRB Level 1 assessment for WRIA 25 & 26 (2001) presents average current water usage in 2000 (surface water) for the Coweeman River as 29.4 million gallons/day, which translates to 45.5 cfs. Total water rights for the Coweeman are listed as an annual quantity of 1336 AcreFeet/Year or an instantaneous quantity of 16,570 gpm (37cfs). Exhibit 4-1 presents a figure of surface water rights distribution, which is clustered in the lower reaches of the Coweeman and Lower Cowlitz Rivers. Median low flow (July to September) for the Coweeman is 50 cfs (Caldwell 1999). Usage seems to be significant, but usage data by month was unavailable. Therefore, a comparison of usage during low flow months was not possible. The effects of these withdrawals on low flow are unknown. It was assumed that if the bulk of these withdrawals occur in the lowest reaches there would likely be a decrease in low flows there as well, with the cumulative effect being the greatest in Coweeman 1- tidal and 2; these reaches were given a rating of 2.5.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Flow – Intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. This attribute was given an EDT rating of 0 for current conditions due to the lack of storm water runoff and hydroelectric development in the watershed. There are no major metropolitan areas in this watershed with large areas of impervious surfaces.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in this watershed. Based on USFS watershed analyses and a Q2yr analysis for the Kalama River, it was assumed peak high flows increased by 13%. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in interannual variability in high flows (pers. com. Lestelle, Mobrand Biometrics, Inc). Ratings for interannual variability in high flow were translated directly into ratings for intra-annual flow.
*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. Stream length was assumed to be the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. To determine if surveys were conducted during average low flow conditions, streamflows corresponding to survey dates were compared to mean August flows (for all available years). USGS (2004) streamflow data was not available for the Coweeman River in 2002, however, gauge data from the South Fork (SF) Toutle River (near Toutle, WA) and East Fork (EF) Lewis River (near Heisson, WA) were assumed to be good surrogates for identifying fluctuations in streamflow caused by rain events. Mean August streamflow for the SF Toutle (1940-2002) was 118 cfs (range: 79 to 172 cfs), and flows corresponding to 2002 survey dates were 67, 71 and 371 cfs (USGS 2004). Mean August streamflow for the EF Lewis (1930-2002) was 83 cfs (range: 44 to 278 cfs), and flows corresponding to 2002 survey dates were 47, 49, and 301 cfs (USGS 2004). It was assumed conditions on the Coweeman River were similar. Widths measured on the first and second survey dates may be biased slightly low, and those measured on the third slightly high, but in general surveys were conducted during near average low flow conditions.

Where representative reach data (VanderPloeg 2003) was available, it was used in rating the corresponding EDT reaches. Minimum wetted widths for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement and/or by using the “split rule” (). The “split rule” is defined as follows: for reaches above a split (confluence of 2 tributaries), or where significant tributaries entered the mainstem, wetted width was calculated by: [(1.5*downstream reach width)*0.5] for even splits. For uneven splits, the multiplier was adjusted to compensate: in a 60:40 split: [(1.5*drw)*0.6] and [(1.5*drw)*0.4]; for a 70:30 split: **[**(1.25*drw)*0.7] and [(1.25*drw)*0.3]; and for an 80:20 split: [(1.25*drw)*0.8] and [(1.25*drw)*0.2]. The “split rule” was applied by working both upstream and downstream between surveyed reaches.

**Table E7-10. EDT reaches surveyed and/or split (using the "split rule") to develop minimum widths for non-surveyed reaches.**

| EDT Reaches Surveyed/Split | Split Rule used | Non –surveyed Reaches Applied To |
|---|---|---|
| **Canyon 2** | None | Coweeman 1 - 4 & Canyon 1 |
| Coweeman 5 | **70**/30 | Coweeman 5 & Canyon 3 |
| **Coweeman 9** | **70**/30 | Coweeman 6 - 9 |
| Coweeman 10 | **70**/30 | Coweeman 10 |
| Coweeman 12 | **70**/30 | Coweeman 11 & 12 |
| **Coweeman 15** | None | Coweeman 13 - 15 |
| Coweeman16 | **70**/30 | Coweeman 16 - 22 |
| Coweeman16 | 80/**20** | Brown, O'neill, Martin, Nineteen, Nye, Sam Smith, Skipper, Turner |
| **Baird 1** | **None** | Baird 1 |
| **Baird 1** | **70**/30 | Baird 2 & 3 |
| **Baird 1** | 70/**30** | Little Baird, Jim Watson, LB Trib 1-6, RB Trib 1-7 |
| **NF Goble** | None | NF Goble |
| **NF Goble** | **60**/40 | Goble 1, Mulholland 1 |
| Mulholland 1 | **80**/20 | Mulholland 2 |
| Mulholland 2 | **70**/30 | Mulholland 3 & 4 |
| Goble 1 | **60**/40 | Goble 2 |
| Goble 2 | **50/50** | Goble 3 & 4 |
| **Bold Type** indicates surveyed reaches (VanderPloeg 2003) & the portion of the split rule applied. | | |

Hydroconfinement in Coweeman 1-tidal & Coweeman 2 was not thought to significantly reduce minimum width and values for these reaches were applied to both the current and historical conditions.

*Level of Proof*—A combination of empirical observations, expansion of empirical, observations, derived information and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations, derived information and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in lower Columbia River tributaries were surveyed by Steve VanderPloeg (WDFW) in 2003. Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys. To determine if surveys were conducted during average high flow conditions, streamflows corresponding to survey dates were compared to mean January flows (for all available years). USGS (2004) streamflow data is not available for the Coweeman River in 2000 and 2002, however, gauge data from the South Fork (SF) Toutle River (near Toutle, WA) and East Fork (EF) Lewis River (near Heisson, WA) were assumed to be good surrogates for identifying fluctuations in streamflow caused by rain events. Mean January streamflow for the SF Toutle (1940-2002) was 1031 cfs (range 318 to 2488 cfs), and flow corresponding to the 2003 survey date was 819 cfs (USGS 2004). Mean January streamflow for the EF Lewis (1930-2002) was 1407 cfs (range 303 to 3459 cfs), and flow corresponding to the 2003 survey date was 892 cfs (USGS 2004). SF Toutle and EF Lewis flows were both slightly lower than average. It was assumed conditions on the Coweeman River were similar, indicating surveys were conducted during near average flow conditions. Wetted widths recorded during these surveys were used without adjustment, realizing they may be biased slightly low.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. The percent increase between low and high flow widths for all subbasins was compared to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data (EDT reach Kalama 14). A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Using only Kalama mainstem reach data (EDT reaches Kalama 2, 5, 11, 17) the mean increase in stream width is 30%. A possible explanation for this is that most of the Lower Kalama watershed is currently confined and/or hydroconfined. Based on this data, general "rules" were developed relating wetted width minimum and maximum values. A 1.6 multiplier (60%) was assumed to be appropriate for expanding wetted width minimum values in reaches with moderate confinement and in all tributary reaches. In unconfined mainstem reaches, where down-cutting has not occurred, it was assumed minimum widths would (on average) double under average high flow conditions, and a 2.0 (100%) multiplier was used for these reaches. Conversely, in heavily confined mainstem areas (i.e. canyons) it was assumed minimum widths can not increase much as flow increases and a 1.3 (30%) multiplier was used in these reaches.

For the Coweeman, actual "wetted width-high" values were used in reaches where data was available from surveys. For reaches without high flow width data, the rules described above were used to expand "wetted width-low" values. The 1.6 multiplier was used on all tributary and mainstem reaches except as follows. The 1.3 multiplier was used on confined/hydroconfined mainstem reaches Coweeman 1-tidal, 2, 12, 13, Canyon1 & 3. Unconfined reaches of the lower Coweeman (Coweeman 1-tidal & 2) are currently heavily diked and channelized. In the historic condition these areas were likely more braided and wider during winter flows. The 2.0 multiplier was used to develop historic "wetted width-high" values for these reaches.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

## Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as % gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003. Confinement ratings were estimated during these surveys (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps (1:24,000) were consulted (via GIS) to verify and/or adjust ratings. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4 (Table E7-11). There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings.

**Table E7-11. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures and activity) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. Most hydro-modification consists of roads in the floodplain and diking. The SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, USGS topography maps (1:24,000 via GIS), and WRIA 26 LFA (Wade 2000) were reviewed and professional judgment was used to assign EDT ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.

*Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Glides* is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, it was assumed that for historical conditions the percentage of pools was significantly higher than for current conditions. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, pool habitat was estimated to be 40% and 30% respectively (WFPB 1994). Tailouts were assumed to represent 15-20% of pool habitat, which is the current range from WDFW surveys (VanderPloeg 2003). Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data (VanderPloeg 2003) indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

Representative reaches of lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Surveys primarily followed USFS stream survey level 2 protocols, which delineate between riffles and slow water, but not pools and glides. Glide habitat is the most difficult habitat to identify, and, therefore, was estimated but not surveyed. In general, WDFW survey methodology did not appear to work for glides. Therefore, Wind River data (USGS) was examined to help differentiate between these two habitat types. Wind River data showed a positive relationship between gradient and/or confinement and riffle habitat. It also showed a negative relationship between pool habitat and gradient and/or confinement. However, there was no relationship between pools and glides. There was variation between surveyors when the same reach was walked. This may be due to habitat changes but it could also be due to measurement error between surveyors. In general, glides accounted for 30% to 50% of the non-riffle habitat.

For the Coweeman, habitat types were measured by VanderPloeg (WDFW 2003) within mainstem EDT reaches Canyon 2, Coweeman 9 & 15, and tributary reaches North Fork Goble and Baird Creeks. The three mainstem reaches and the two tributary reaches were averaged to develop representative ratings for the two categories, respectively. Back-water pools were thought to be minimal in the mainstem, due to confinement, and ratings were reduced to 0. Tailout percentages for mainstem and tributary ratings were adjusted to be 20% of pool habitat. After adjustment, glide habitat for the averaged mainstem reach data was 62.9 % of non-riffle habitat, and 48.4% for averaged tributary data. The mainstem Coweeman has many areas of confined bedrock canyon with long sections of pool/glide habitat. Based on this and comparison with Wind River data, Coweeman River glide percentage estimates seemed reasonable and no further adjustments were made.

All tributary reaches on the Coweeman are >=1.5% gradient and confined; averaged habitat ratings were thought to be representative and were applied to all Coweeman tributaries. Averaged mainstem habitat ratings were applied to all mainstem reaches with the following exceptions. Coweeman 1-tidal & 2 are currently hydroconfined by diking and were rated as 100% glides. Historically these reaches likely were meandering, low-gradient, braided streams with increased back-water pools and gravel riffles and were rated as such. Canyon 1 currently has a gravel pit operation within the reach and several old gravel pits have increased backwater pools in this reach. Backwater pool habitat was increased for this reach under current conditions.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. Most of the Coweeman basin is confined with some areas of moderate confinement. An EDT rating of 0% off-channel was assigned to moderately confined/confined reaches. Only the lowest reaches are completely unconfined (Coweeman 1 – 4). For the historic condition, Coweeman 1, 2, 3 and 4 were given EDT ratings of 20%, 20%, 5%, and 1% off-channel habitat, respectively. Currently, these reaches are diked and channelized and have little if any off-channel habitat (~1%).

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*—Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*—Currently, there are no barriers identified in the Coweeman Basin EDT model. Most tributaries are represented in the EDT model by a single reach. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon are more impacted by barriers, due to their preference for spawning in small tributaries. As barrier inventories become more complete and available for the Coweeman Basin it would be valuable to incorporate these into the EDT model.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. By definition, all reaches were given an EDT rating of 0 for the historical condition.

EDT reaches Coweeman 1- tidal & 2 run through the town of Kelso, Washington, and are heavily diked and channelized. Coweeman 3 is an agricultural area and likely has withdrawals for irrigation and livestock. Above Coweeman 2, the watershed is rural with limited stream adjacent housing, and runs through narrow canyons and/or private land managed for timber harvest (i.e. The Mark Andrews Tree Farm). The majority of homes adjacent to the stream occur in reaches Coweeman 8-14, Goble Creek 1 & 2, and NF Goble Creek. EDT reaches above Baird Creek are behind closed gates on private lands primarily owned and managed by Weyerhaeuser for timber harvest. Most tributary reaches, except Goble Creek, are sparsely populated and/or on private lands managed for timber harvest. The intake for the lower Coweeman steelhead acclimation pond (operated by Cowlitz Game & Anglers) is located on Turner Creek. The intake is gravity fed and screened. Water is returned to Turner Creek at the lower end of the pond. Withdrawals in these areas are thought to be minor or non-existent.

The LCFRB Level 1 assessment for WRIA 25 & 26 (2001) presents average current water usage in 2000 (surface water) for the Coweeman River as 29.4 million gallons/day, which translates to 45.5 cfs. Total water rights for the Coweeman are listed as an annual quantity of 1336 AF/Year or an instantaneous quantity of 16,570 gpm (37cfs). In comparison, median low flow (July to September) for the Coweeman is 50 cfs (Caldwell 1999). Exhibit 4-1 of the Level 1 assessment presents a figure of surface water rights distribution, which is clustered in the lower reaches of the Coweeman and lower Cowlitz. Water rights identified were small scale and likely equate to limited withdrawals for domestic and agricultural use. Specific areas of significant single-source water withdrawals were not identified, however the cumulative effects of small scale withdrawals may equate to significant total water usage during low flow periods.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table developed by Dan Rawding (WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table is based on professional judgment. It relates bed scour to confinement, wetted width (high flow), and gradient and assumes scour increases as gradient and confinement increase. In Coweeman 1-tidal, where scour likely occurred during low tides and high flow events, the look-up table rating was reduced by ½.

Historic EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as follows: it was assumed increases in peak flow and hydroconfinement also increased bed scour, and scour ratings were increased 0.049 for each tenth (0.1) of increase in the EDT peak flow rating and for each point (1.0) increase in the hydroconfinement rating. In Coweeman 1-tidal and 2, where reaches are currently slough-like (mud bottom), bed scour was rated by reducing the current look-up table rating by ½.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—Most Lower Coweeman EDT reaches are rainfall dominated. EDT reaches Coweeman 19 – 22, Baird 1-3, Mulholland 1-4, Little Baird, LB6 and RB7 were rated as rain-on-snow transitional. Anchor ice and major icing events are rare or non-existent. EDT ratings of 0 were assigned to all reaches in the historical and current condition.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. For current conditions, riparian zones with mature conifers are rated at 1.0. Riparian zones with saplings and primarily deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees are rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When vegetation is lacking and/or hydroconfinement/residential development exists, riparian ratings were increased based upon the severity of each.

Information on the status of riparian zones in the Coweeman watershed was compiled from: the LFA for WRIA 26 (Wade 2000), EDT Habitat Surveys by WDFW (VanderPloeg 2003), the SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000 via GIS). EDT reaches Coweeman 1- tidal & 2 run through the town of Kelso, Washington, and are heavily diked and channelized. Above Coweeman 2, the watershed is rural with limited stream adjacent housing, and runs through narrow canyons and/or private land managed for timber harvest. The LFA for WRIA 26 (Wade 2000) describes riparian conditions as “generally poor throughout the Coweeman subbasin”, due to diking in the lower reaches and agricultural activities/forest practices throughout. WDFW habitat surveys (VanderPloeg 2003) were conducted in EDT reaches Coweeman 9 & 15, Canyon 2, NF Goble, and Baird Creek. Notes on riparian composition were taken as part of these surveys. Most reaches had a mix of alder, big-leaf maple, Douglas fir, cedar, and hemlock at various stages of growth. While all areas surveyed had conifers within the reach, stands of old/mature conifers were noted as being sporadic, most were described as “even aged” indicating areas of re-growth after logging. Stream adjacent roads and visible clear-cuts outside of buffer areas were noted in many areas.

Coweeman 1 & 2 are diked and channelized with few trees, and were given an EDT rating of 3. Coweeman 3 and 4 run through agricultural areas. Much of the south bank in these reaches is bordered by fields used for grazing livestock with down-cut banks and sporadic deciduous trees, while the north bank is forested with a deciduous/coniferous mixture. These reaches were given a rating of 1.5. All other reaches with vegetated riparian zones and no hydroconfinement were given a rating of 1.0, with the following exceptions. Canyon reaches, where riparian function (except shade) is near 100%, were rated at 0.5. Tributary reaches, where ortho-photos showed fresh clear-cuts adjacent to the stream and little or no buffer, were rated between 1.5 and 2.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*— In general, the template condition for wood in Lower Columbia River tributaries was assumed to be at an EDT rating of 0 (complex mixture/plentiful) for all areas except large canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind Rivers, which likely did not hold LWD as well. These areas were assumed to be at a rating of 1 to 2, based on the width and length of the canyon. For the Coweeman watershed, mainstem canyon reaches Canyon 1 - 3 and Coweeman 13 were given an EDT rating of 2 for the template condition. All other reaches were given an EDT rating of 0.

The Timber Fish and Wildlife (TFW) Effectiveness Monitoring Report entitled “A Watershed-Scale Baseline Inventory of Large Woody Debris in the Upper Coweeman WAU” (Volkhardt 1999) presents LWD counts and densities for many stream segments in the Coweeman subbasin above Mulholland Creek. Volkhardt (1999) expresses LWD densities as pieces per channel width (CW) using bank full width as CW. For EDT purposes these densities may be biased high, as LWD densities for EDT are calculated as pieces/CW where CW equals the average wetted width during the high flow month (< bank full). Despite this potential bias, these LWD densities represent the best and most complete data set available for the Coweeman subbasin and were used without adjustment. Using figure 2 of Volkhardt’s report, surveyed segments were linked to their corresponding EDT reach(s) (Table E7-12). Additionally, LWD counts were made in several lower Coweeman EDT reaches during WDFW Habitat surveys (VanderPloeg 2003) and WDFW steelhead redd surveys (spring 2003) using EDT protocol (Table E7-13).

These three data sources were used to generate EDT LWD ratings for the Coweeman watershed as follows. LWD densities for each surveyed segment were, first, converted to EDT ratings according to EDT definitions (Table E7-12 and Table E7-13 ). EDT ratings were averaged for all surveyed mainstem segments above Coweeman 12 (Mulholland Creek upstream), generating an average rating of 2.5, which was applied to Coweeman 13 – 22. Similarly, ratings from surveyed reaches between Coweeman 5 and 12 were averaged to generate a rating of 3.5 for these reaches. A rating of 3.6 from a survey conducted in Canyon 2 was applied to reaches Coweeman 3 & 4 and Canyon 1 - 3. No surveys were conducted in Coweeman 1-tidal or 2. These reaches were assumed to have low LWD densities and were given an EDT rating of 4. EDT ratings from surveys conducted in tributary reaches were assumed to representative of the entire reach and were used to rate the reach. If more than one survey was conducted within a tributary reach, the average reach rating was used. The average EDT rating for all tributary segments surveyed was 2.4. Based on this, non-surveyed tributary reaches were given a categorical rating of 2.

**Table E7-12. Coweeman subbasin stream segments surveyed by Volkhardt (1999) and the corresponding EDT reach names and EDT LWD ratings.**

| Stream Name | Volkhardt 1999 Segment # | Approximate EDT Reach | EDT Rating |
|---|---|---|---|
| Coweeman | 2 | Coweeman 13 | 1.4 |
| Coweeman | 4 | Coweeman 13 | 2.4 |
| Coweeman | 6 | Coweeman 14 & 15 | 2.7 |
| Unnamed | 11 | No EDT reach | 3.3 |
| Unnamed | 23 | LB 4 | 0.5 |
| Unnamed | 37 | RB 4 | 3.9 |
| Unnamed | 38 | RB 4 | 3.7 |
| Unnamed | 40 | RB 4 | 3.6 |
| Unnamed | 50 | No EDT reach | 3.4 |
| Sam Smith Ck | 60 | Sam Smith | 3.4 |
| Blackman Ck | 69 | No EDT reach | 3.7 |
| Mulholland | 103 | Mulholland 2 | 3.2 |
| Mulholland | 104 | Mulholland 2 | 1.4 |
| Mulholland | 105 | Mulholland 2 | 2.4 |
| Mulholland | 106 | Mulholland 2 | 0.1 |
| Mulholland | 107 | Mulholland 2&3 | 0.4 |
| Mulholland trib | 125 | LB 5 | 3.1 |
| Mulholland trib | 138 | No EDT Reach | 2 |
| Mulholland trib | 146 | No EDT Reach | 1.5 |
| Mulholland trib | 150 | No EDT Reach | 3.1 |
| Baird | 201 | Baird 1 | 0.3 |

| Stream Name | Volkhardt 1999 Segment # | Approximate EDT Reach | EDT Rating |
|---|---|---|---|
| Baird | 203 | Baird 1 | 1.7 |
| Little Baird | 224 | Little Baird | 2.5 |
| Little Baird | 225 | Little Baird | 2.2 |
| Baird Crk. Trib | 243 | No EDT reach | 1.8 |
| Nineteen | 250 | Nineteen | 2 |
| Coweeman | 300 | Coweeman 16 & 17 | 1.8 |
| Coweeman | 301 | Coweeman 18 | 1.1 |
| Coweeman | 303 | Coweeman 18 & 19 | 3 |
| Coweeman | 304 | Coweeman 19 | 2.8 |
| Coweeman | 305 | Coweeman 21 | 2.4 |
| Coweeman | 306 | Coweeman 22 | 1.5 |
| Unnamed | 322 | Martin Ck | 0.8 |
| Brown | 328 | Brown | 2.7 |
| Brown trib | 333 | No EDT Reach | 2.2 |
| Brown trib | 338 | No EDT Reach | 3.8 |
| Skipper | 346 | Skipper | 3.4 |
| Skipper | 347 | Skipper | 3.3 |
| Skipper trib | 353 | No EDT Reach | 2.7 |
| O'neil | 361 | O'neil | 0.3 |
| O'neil | 362 | O'neil | 0.5 |
| O'neil trib | 372 | No EDT Reach | 2.7 |
| Coweeman | 401 | Above Washboard Falls | 0.5 |
| Coweeman | 403 | Above Washboard Falls | 0.9 |
| Coweeman | 406 | Above Washboard Falls | 0.5 |
| Coweeman Trib | 413 | Above Washboard Falls | 0 |
| Coweeman Trib | 414 | Above Washboard Falls | 0.3 |
| Coweeman Trib | 423 | Above Washboard Falls | 0.3 |
| Butler | 460 | Above Washboard Falls | 2.4 |
| Butler | 461 | Above Washboard Falls | 2 |
| Butler | 476 | Above Washboard Falls | 3.6 |

**Table E7-13. Coweeman EDT reaches where LWD counts were conducted during WDFW stream surveys and the corresponding EDT LWD ratings.**

| EDT Reach | Data Source | EDT Rating |
|---|---|---|
| Canyon 2 | WDFW Habitat Survey - VanderPloeg 2003 | 3.6 |
| Coweeman 9 | WDFW Habitat Survey - VanderPloeg 2003 | 3.7 |
| NF Goble Cr | WDFW Habitat Survey - VanderPloeg 2003 | 4 |
| Coweeman 15 | WDFW Habitat Survey - VanderPloeg 2003 | 3.1 |
| Baird 1 | WDFW Habitat Survey - VanderPloeg 2003 | 2.3 |
| Baird 1 | WDFW Steelhead Redd Survey - 2003 | 1.9 |
| Baird 1 | WDFW Steelhead Redd Survey - 2003 | 3.1 |
| Coweeman 10,11,12 | WDFW Steelhead Redd Survey - 2003 | 3.1 |
| Coweeman 7,8,9 | WDFW Steelhead Redd Survey - 2003 | 3.7 |
| Coweeman 15 | WDFW Steelhead Redd Survey - 2003 | 3.8 |
| Coweeman 13 | WDFW Steelhead Redd Survey - 2003 | 3.8 |
| Mulholland 1 | WDFW Steelhead Redd Survey - 2003 | 2.8 |
| Mulholland 1 | WDFW Steelhead Redd Survey - 2003 | 2.9 |
| Goble 1 | WDFW Steelhead Redd Survey - 2003 | 3.7 |
| Goble 3 | WDFW Steelhead Redd Survey - 2003 | 3.3 |
| Goble 2 | WDFW Steelhead Redd Survey - 2003 | 3.7 |
| Goble 2 | WDFW Steelhead Redd Survey - 2003 | 3 |
| NF Goble | WDFW Steelhead Redd Survey - 2003 | 3.6 |
| NF Goble | WDFW Steelhead Redd Survey - 2003 | 3.3 |

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate the percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) examined the relationship between road density and fine sediment levels in coastal watersheds of Washington State's Olympic Peninsula region, and found that as road density increased by 1 km/sq.km fine sediment levels increased by 4.3% (2.65% per 1 mi./sq.mi.) However, Duncan and Ward (1985) found a lower increase in percentage of fines in southwest Washington, but attributed much of the variation in fines to different soil types. The Wind River is a Lower Columbia River tributary located in SW Washington and is likely representative of other watersheds in the region. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 mi/mi$^2$ of roads for all watersheds ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 mi/mi$^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored, was excluded. Rather than use all three years of Layout Creek data, only the median was used and the final relationship used for EDT was a 1.34% increase in fines per 1 mi/mi$^2$ ($R^2$=0.56, n=15) (Figure E7- 1).

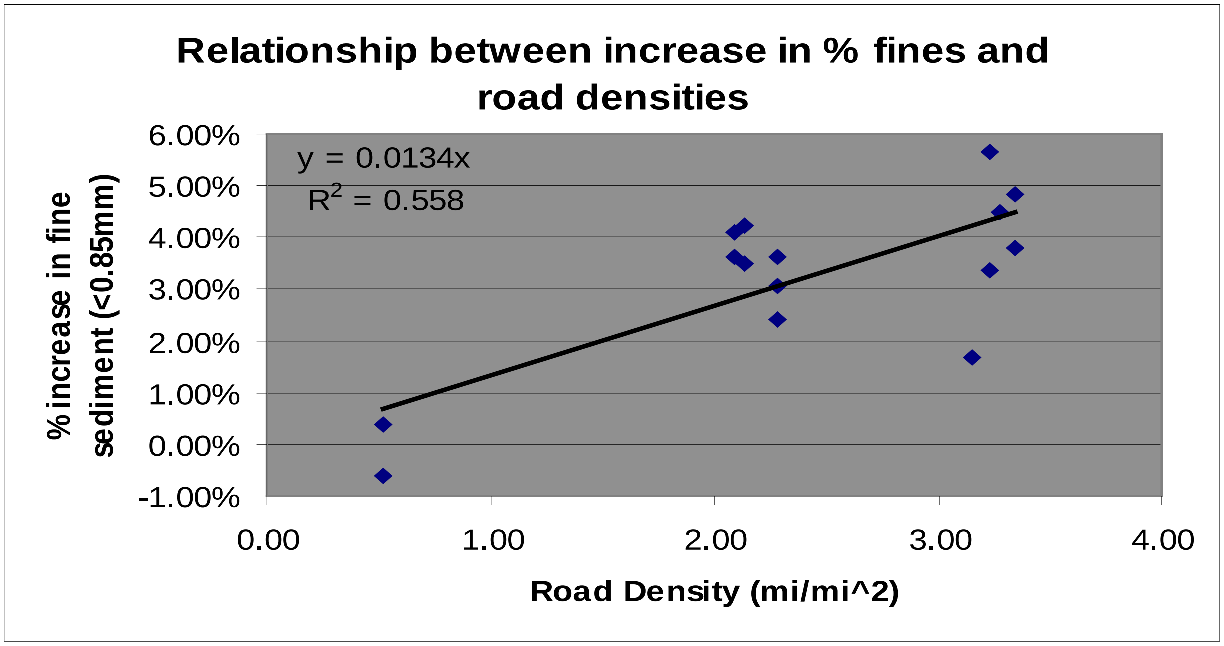


**Figure E7- 1**. **Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

Coweeman River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries. Table E7-14 presents IWA road density by HUC for HUCs with associated EDT reaches. An exception to this is Coweeman 1- tidal and Coweeman 2. These reaches, with lower gradients and diking, are slough-like and were given an EDT rating of 4 for current conditions.

**Table E7-14. IWA Road Densities for HUCS with Associated EDT Reaches**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship- EDT Fines Rating |
|---|---|---|---|
| 17080005080301 | C7(.5), C8, C9, C10, C11, C12, LB2, LB3, RB3, Jim Watson Cr, Sam Smith Cr | 7.3 | 2.5 |
| 17080005080302 | M1, M2, RB6, LB5 | 6.4 | 2.25 |
| 17080005080303 | C13, C14, C15, RB4, LB4 | 7.5 | 2.57 |
| 17080005080304 | B1, B2, B3, LB6, Little Baird Cr | 5.4 | 2.08 |
| 17080005080305 | RB5, C21, C22 | 4.5 | 1.99 |
| 17080005080306 | M3, M4, RB7 | 5.8 | 2.1 |
| 17080005080307 | C16, C17, C18, C19, C20, Nineteen Cr, Skipper Cr, Brown Cr, O'neil Cr, Martin Cr | 6.4 | 2.25 |
| 17080005080401 | C5, C6, C7(.5), RB2, Canyon 2, Nye Cr | 5.8 | 2.1 |
| 17080005080402 | C2(.5), C3, LB1 | 11.3 | 2.94 |
| 17080005080403 | C4, RB1, Canyon 1, Turner Cr | 6.1 | 2.18 |
| 17080005080404 | NF Goble Cr | 6.6 | 2.25 |
| 17080005080405 | G1, G2, G3, G4 | 6 | 2.15 |
| 17080005080407 | C1 tidal, C2(.5) | 4.8 | 2.03 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*—In rating this attribute it was assumed that percent embeddedness is directly related to the percentage of fines in spawning gravel.

In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), it was assumed embeddedness was less than 10%, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2.

Using the USFS Wind River data and analysis described above for rating fine sediment, a scale was developed relating road density to percent embeddedness. This scale was used to generate embeddedness ratings for all EDT reaches in the watershed. An exception to this is Coweeman 1- tidal and Coweeman 2. These reaches, with lower gradients and diking, are slough-like and were given an EDT rating of 3 for current conditions.

Coweeman River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries. Table E7-15 presents IWA road density by HUC for HUCs with associated EDT reaches.

**Table E7-15. IWA Road Densities for HUCS with Associated EDT Reaches**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Emb. Rating |
|---|---|---|---|
| 17080005080301 | C7(.5), C8, C9, C10, C11, C12, LB2, LB3, RB3, Jim Watson Cr, Sam Smith Cr | 7.3 | 1 |
| 17080005080302 | M1, M2, RB6, LB5 | 6.4 | 0.89 |
| 17080005080303 | C13, C14, C15, RB4, LB4 | 7.5 | 1.05 |
| 17080005080304 | B1, B2, B3, LB6, Little Baird Cr | 5.4 | 0.81 |
| 17080005080305 | RB5, C21, C22 | 4.5 | 0.78 |
| 17080005080306 | M3, M4, RB7 | 5.8 | 0.84 |
| 17080005080307 | C16, C17, C18, C19, C20, Nineteen Cr, Skipper Cr, Brown Cr, O'neil Cr, Martin Cr | 6.4 | 0.89 |
| 17080005080401 | C5, C6, C7(.5), RB2, Canyon 2, Nye Cr | 5.8 | 0.84 |
| 17080005080402 | C2(.5), C3, LB1 | 11.3 | 1.37 |
| 17080005080403 | C4, RB1, Canyon 1, Turner Cr | 6.1 | 0.87 |
| 17080005080404 | NF Goble Cr | 6.6 | 0.9 |
| 17080005080405 | G1, G2, G3, G4 | 6 | 0.85 |
| 17080005080407 | C1 tidal, C2(.5) | 4.8 | 0.8 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process that occasionally increased turbidity after an extensive hot burn. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels at an EDT rating of 0 in small tributaries (<35 ft. ww-high), 0.3 in medium tributaries (>35 ft. ww-high), and 0.5 in mainstem reaches.

Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (2004). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout Creek, Panther Creek, and the Middle Wind are over 40 mg/L, and other basins are 5-40 mg/L with most less than 25 mg/L. However, the duration of these turbidity levels is unknown. If suspended sediment levels of 100 mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L levels last 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support EDT ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for lower mainstem reaches.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*— Historical temperatures are unknown the in the Coweeman River subbasin. The only historical temperature data that was located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary processes transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2000). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches can be estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next it was assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, 49 meters was used as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, the relationship between forest angle and percentage of shade was used (WFPB 1997 Appendix G-33). Finally, the relationship between elevation, percentage of shade and the maximum daily stream temperature was used to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams, our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. A correction factor was developed for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

For current conditions, the EDT maximum temperature calculator (MS Access) provided by Mobrand Biometrics, Inc. (MBI) was used to generate ratings for reaches where temperature data was available. Temperature data corresponding to summertime low flows (August) was available from the Cowlitz/Wahkiakum Conservation District (pers. com.), and Sullivan et. al. (1990). Table E7-16 lists the EDT reaches where temperature data was available, the year data was collected, and the data source. Temperature data collected within an EDT reach was assumed to be representative of the entire reach and was used to generate an EDT rating for the reach. Ratings for mainstem reaches without temperature data were extrapolated based on elevation, and proximity to reaches with temperature data. For tributaries, current and historic EDT ratings for reaches with current temperature data were compared, indicating that on average current ratings are 1 point higher than historic ratings. This relationship was used to develop ratings for tributary reaches without temperature data.

**Table E7-16. Coweeman River EDT reaches with August temperature data, the year data was collected, & the data source.**

| EDT Reach | Year | Temperature Data Source |
|---|---|---|
| Coweeman 4 | 2002 | Cowlitz/Wahkiakum Cons. Dist. |
| Canyon 1 | 1988 | Sullivan et. al. 1990 |
| Coweeman 5 | 2002 | Cowlitz/Wahkiakum Cons. Dist. |
| Coweeman 6 | 1988 | Sullivan et. al. 1990 |
| Coweeman 13 | 1988 | Sullivan et. al. 1990 |
| Coweeman 16 | 1988 | Sullivan et. al. 1990 |
| Baird 1 | 1988 | Sullivan et. al. 1990 |
| Goble 1 | 2002 | Cowlitz/Wahkiakum Cons. Dist. |
| Goble 1 | 1988 | Sullivan et. al. 1990 |
| Jim Watson Creek | 2002 | Cowlitz/Wahkiakum Cons. Dist. |
| Mulholland 1 | 1988 | Sullivan et. al. 1990 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Minimum temperature data was lacking in the basin. Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) –5.8305 ( $R^2$= 0.32, n=27). This relationship was used to generate categorical ratings (Table E7-17) based on elevation.

**Table E7-17. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

Minimum temperature ratings were assigned to both the historical and current conditions. Tributary ratings were assigned based on the elevation at the mouth unless they have more than one reach. In this case, elevations within each reach were used.

*Level of Proof*—A combination of expanded empirical observations, derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

## Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—No data was found regarding current or historical conditions for groundwater inputs in this basin. Historically, there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries in the upper watershed likely had less groundwater input. These reaches were given an EDT rating of 2. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS (2004) data for conductivity using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). Conductance data was available from three stations on the Coweeman, two near Kelso, WA and one above Sam Smith Creek. Conductance/Alkalinity data was averaged for these three locations and used to develop an EDT rating of 2.2 for the watershed. Alkalinity in the historic condition was given the same rating as the current condition for all reaches.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired, an EDT rating of 0 (>8mg/l in August). Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. For the Coweeman River, USGS (2004) water quality data (1971 & 1975) collected at gauging station 14244600 above Sam Smith Creek (Coweeman 12) indicate dissolved oxygen levels averaged 9.2 mg/l in August. Data from this site from 1970 - 1975 show no excursions below 8 mg/l during sampling. All reaches of the Coweeman were assumed to have greater than 8mg/l of DO with the following exceptions. USGS (2004) water quality data (1961-1972) collected at gauging station #14245000 indicates dissolved oxygen levels averaged 7.5 mg/L in August. This site is at the lower end of EDT reach Canyon 1. Reaches below this (Coweeman 1 tidal – 4) are unconfined and low gradient with little shade. Coweeman 3 and 4 pass through fields used for grazing livestock and are down-cut. Coweeman 1-tidal and 2 run through the town of Kelso, Washington and are diked/channelized and slough-like. Summertime water temperatures likely increase in these areas and DO problems may be exacerbated. Coweeman 4 was given an EDT rating of 0.7 and Coweeman 1-tidal, 2 & 3 were rated at 1.0.

*Level of Proof*— A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. There is more uncertainty in the ratings for reaches with sloughs or slough-like conditions, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because, of the lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

An exception to this is Coweeman 1-tidal. With the tidal influence in this reach, there is likely some water exchange with the lower Cowlitz during flood/high tides. The LFA for WRIA 26 (Wade 2000) notes that "the lower Cowlitz was placed on the 1998 303d list for 3 excursions beyond the National Toxic Rule criterion out of three samples for levels of arsenic". Coweeman 1-tidal was given an EDT rating of 0.5.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

An exception to this is Coweeman 1-tidal. With the tidal influence in this reach, there is likely some water exchange with the lower Cowlitz during flood/high tides. The LFA for WRIA 26 (Wade 2000) notes that "the lower Cowlitz was placed on the 1998 303d list for 3 excursions beyond the National Toxic Rule criterion out of three samples for levels of arsenic". Coweeman 1-tidal was given an EDT rating of 0.5.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically, nutrient enrichment did not occur because, by definition, watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches under current conditions the following factors were examined: fertilizing by timber companies, reaches downstream from fish hatcheries, agriculture effects, septic tanks, and storm water run-off.

The Coweeman has no fish hatcheries within the watershed. Most of the Coweeman River subbasin above EDT reach Coweeman 10 is owned by Weyerhaeuser and managed for timber harvest as part of the Mount St. Helens South Tree Farm. Stream adjacent homes in this area are rare. Weyerhaeuser utilizes the following protocol for fertilizing the Mount St. Helens North and South Tree Farms (pers. com. Byron Richert, Weyerhaeuser): fertilizer is applied aerially (via helicopter), the fertilizer used is Urea 46-00-0 applied at 440 lbs./acre (210 lbs. active Nitrogen), only Douglas Fir responsive stands (>50% Douglas Fir) are fertilized, fertilization starts at age 18 and is conducted once every seven years until three years before harvest. The effects of this fertilization on stream enrichment are likely difficult to measure, but were assumed to be minimal.

Most enrichment in the watershed likely occurs from stream adjacent septic systems, agriculture and industry. Stream adjacent homes are sporadic throughout the watershed from EDT reach Canyon 1 up to Coweeman 11 (end of county road) and in Goble 1 & 2. Reaches Canyon 1 to Coweeman 11, and Goble 1 & 2 were given an EDT rating of 0.1. Coweeman 3 and 4 are agricultural reaches with a significant amount of livestock grazing and unfenced streambanks and were given a rating of 1.0. Coweeman 1-tidal and 2 run through the City of Kelso, Washington industrial area; storm water runoff from this area likely increases enrichment. Coweeman 1-tidal and 2 were given a rating of 1.5. All other reaches were rated at 0.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds. Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness in SW Washington watersheds was estimated from direct observation (stream surveys, snorkel surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, local knowledge, and expert opinion. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer, which was captured in the EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Abernathy, Germany, and Mill creeks (pers. com. Hanratty, WDFW), smolt trapping activities on the Kalama River above Lower Kalama Falls (pers. com. Wagemann WDFW), (3) electro-shocking in 2002 by USFWS in Abernathy Creek (pers. com. Zydlewski, USFWS), (4) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (5) WDFW stream & snorkel surveys on the Elochoman (pers. com. Byrne, WDFW), Kalama, East Fork Lewis, Toutle and Coweeman Rivers, (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and

Bond (1967), and (7) McPheil (1967). A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls).

EDT reaches Coweeman 1-tidal and 2 likely have many species present from the Lower Columbia and Lower Cowlitz Rivers. An estimated 30+ species were included in this list: Chinook, chum, coho, steelhead/rainbow trout, cutthroat trout, sculpin sp.(3) (torrent, coastrange, reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback, and dace. Most of the non-native fish species likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW). For EDT reaches Coweeman 3 and 4, Chinook, chum, coho, steelhead/rainbow trout, cutthroat trout, sculpin sp.(3), largescale sucker, peamouth, northern pikeminnow, 3-spine stickleback, and Eastern banded Killifish were assumed to be present. All mainstem and tributary reaches above Coweeman 4 (Canyon 1 upstream) were assumed to have coho, steelhead/rainbow trout, cutthroat trout, and sculpin sp.(2). In addition, Chinook were assumed to be present in mainstem reaches up to Brown's Creek (Coweeman 18) and in tributary reaches Goble 1 and Mulholland 1.

*Level of Proof*— A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. Introduced species ratings were derived from current fish species richness data (see Fish Community Richness above). Coweeman 1-tidal and 2 are the reaches most likely to harbor introduced species. The Eastern banded killifish is the only non-native species documented to penetrate into higher reaches of SW Washington watersheds.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery steelhead constitute the only hatchery releases in the Coweeman Basin. Annual releases are acclimated at two locations in the lower Coweeman. One acclimation pond is on Turner Creek above EDT reach Canyon 1, and the other is on an unnamed tributary entering in EDT reach Coweeman 6.

Mainstem reaches from Coweeman 6 to the mouth and Turner Creek were given and EDT rating of 2. All other reaches were rated at 0.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants and pathogen levels were assumed to be at background levels. All reaches were given an EDT rating of 0.

Hatchery steelhead constitute the only hatchery releases in the Coweeman Basin. Annual releases are acclimated at two locations in the lower Coweeman. One acclimation pond is on Turner Creek above EDT reach Canyon 1, and the other is on an unnamed tributary entering in EDT reach Coweeman 6. Coweeman 6 downstream to the mouth and Turner Creek were given an EDT rating of 2. All other reaches were rated at 0.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

Utilizing GIS, the SSHIAP and DNR roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000) were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use; a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; a rating of 2 was given to reaches with multiple access points (or road parallels reach) through public lands or unrestricted access through private lands; a rating of 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands; and a rating of 0 was given to reaches far from population centers with no roads.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*— By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition.

The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species (i.e. birds) is unknown in this watershed.

Hatchery steelhead smolts are released from acclimation ponds on Turner Creek (above EDT reach Canyon 1) and an unnamed tributary entering in Coweeman 6, potentially increasing predation in downstream reaches. In addition, the potential presence of exotic piscivorous fishes in Coweeman 1-tidal and 2 may increase predation there. Coweeman 1-tidal was given an EDT rating of 4, Coweeman 2 was given a rating of 3, and Coweeman 3 – 6 & Canyon 1-3 were rated at 2.5. All other reaches were given a rating of 2.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Salmon carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Mainstem reaches with historic chum presence (spawning) were given a rating of 0 (super abundant, >800). Mainstem reaches with Chinook and coho, but no chum, were given a rating of 2 (moderately abundant, >200 and <400). Reaches with only coho were given a rating of 3 (not abundant, >25 and <200). Reaches with only steelhead and/or cutthroat trout were given a rating of 4 (very few or none, <25), since these fish can spawn more than once (iteroparous). Tidal reaches below areas of chum spawning were given a rating of 1 (very abundant, >400 and <800); it was assumed carcasses from spawning reaches above are washed into these reaches.

An estimate of the current number of salmon carcasses per mile was derived from natural spawn escapement estimates, EDT reach length data, and SSHIAP fish distribution data. SSHIAP categorizes fish distribution into known, presumed, and potential habitat by species, and EDT reaches were delineated using these categories during development of the EDT template. Using potential fish distribution, EDT reach lengths were summed to develop the total number of miles of habitat available for each species. Where available, the natural spawn escapement estimate was divided by the corresponding number of miles of habitat to generate the average number of carcasses per mile for each species. These values were summed according to the species present within each reach to develop an estimate of the total number of carcasses per mile within the reach. Calculations were completed for chum, Chinook and coho only, as steelhead and cutthroat trout are iteroparous and likely contribute few carcasses. When escapement data was not available, expert opinion was used to estimate escapement and/or carcass abundance.

The Coweeman River currently supports naturally produced populations of fall Chinook, coho, winter steelhead, and cutthroat trout. Chum may exist in low numbers, but fall stream surveys (conducted annually) have not produced any chum carcass recoveries.

WDFW index counts and escapement estimates are available for Coweeman fall Chinook, with the ten year average (1992-2001) being 606 adults. Recent (2002 & 2003) estimates are between 1000 and 1500 adults. For developing EDT carcass estimates, it was assumed 1000 Chinook carcasses were available annually. Estimates of coho abundance are not available for the Coweeman River, but are available for Germany Creek. These were back-calculated from 2001 & 2002 smolt production estimates (pers. com. Hanratty, WDFW). Calculations were made assuming a 4% smolt to adult survival rate, and adding a coho jack estimate calculated as 10% of the total adult run. (pers. com. Seiler, WDFW). Based solely on watershed size, the Germany Creek estimates were doubled and used as surrogate for the Coweeman. Chum carcasses in the Coweeman were assumed to be non-existent.

For current conditions, mainstem Coweeman reaches from Coweeman 18 downstream to the mouth were given an EDT rating of 3, due to the presence of fall Chinook in these areas. All other reaches were given a rating of 4.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the historic and current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. This rating was used as a baseline for benthos diversity and was assigned to all reaches for historic conditions.

Current Wind River data indicates EDT scores in disturbed Rosgen B-channels are similar to historic scores of 0.6 and in disturbed C-channels scores are reduced to 1.3. EDT ratings in Coweeman 2 and 3 were reduced to 1.3. Coweeman 1-tidal is currently, and likely was historically, an area of sediment deposition, and macroinvertebrate complexity is likely reduced. This reach was given a rating of 1.0 and 2.0 for the historic and current conditions, respectively. All other reaches were given a rating of 0.6

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Acknowledgements

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Weyerhaeuser for access to these streams for spawning ground surveys and to collect habitat data used in this modeling effort. We thank the staff at Mobrand Biometrics for running the model especially Kevin Malone and Jennifer Garrow.

| | **Appendix A: EDT reaches and descriptions** |
|---|---|
| **EDT Reach** | **EDT Reach Description** |
| Baird Creek 1 | Description: mouth to Little Baird Creek; Confinement: C; Fish Species present: WS |
| Baird Creek 2 | Description: Little Baird Creek to unnamed LB trib6 at RM 3.7; Confinement: C; Fish Species present: WS—0.3 known, 0.7 presumed |
| Baird Creek 3 | Description: unnamed LB trib6 to extent of presumed steelhead habitat; Confinement: C; Fish Species present: WS presumed |
| Brown Creek | Description: mouth to extent of presumed steelhead distribution (includes both forks); Confinement: C to M; Fish Species present: WS presumed |
| Canyon 1 | Description: downstream end of canyon to Turner Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Canyon 2 | Description: Turner Creek to Nye Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Canyon 3 | Description: Nye Creek to upstream end of canyon; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 1 tidal | Description: mouth to RM 1.0; Confinement: U; Fish Species present: CH, FC, WS |
| Coweeman 10 | Description: unnamed RB trib3 to Jim Watson Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 11 | Description: Jim Watson Creek to Sam Smith Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 12 | Description: Sam Smith Creek to Mulholland Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 13 | Description: Mulholland Creek to unnamed RB trib4; Confinement: C; Fish Species present: FC, WS |
| Coweeman 14 | Description: unnamed RB trib4 to unnamed LB trib4; Confinement: C; Fish Species present: FC, WS |
| Coweeman 15 | Description: unnamed LB trib4 to Baird Creek; Confinement: C; Fish Species present: FC, WS |
| Coweeman 16 | Description: Baird Creek to Nineteen Creek; Confinement: M; Fish Species present: FC, WS |
| Coweeman 17 | Description: Nineteen Creek to Skipper Creek; Confinement: M; Fish Species present: FC, WS |
| Coweeman 18 | Description: Skipper Creek to Brown Creek; Confinement: M; Fish Species present: FC, WS |
| Coweeman 19 | Description: Brown Creek to ONeil Creek; Confinement: C; Fish Species present: FC, WS |
| Coweeman 2 | Description: RM 1.0 to unnamed LB trib1; Confinement: C (diked); Fish Species present: CH, FC, WS |
| Coweeman 20 | Description: ONeil Creek to Martin Creek; Confinement: C; Fish Species present: FC, WS |
| Coweeman 21 | Description: Martin Creek to unnamed RB trib5; Confinement: C; Fish Species present: FC, WS |
| Coweeman 22 | Description: unnamed RB trib5 to Washboard Falls; Confinement: C; Fish Species present: FC, WS |
| Coweeman 3 | Description: unnamed LB trib1 to unnamed RB trib1; Confinement: U; Fish Species present: CH, FC, WS |
| Coweeman 4 | Description: unnamed RB trib1 to downstream end of canyon; Confinement: U; Fish Species present: CH, FC, WS |
| Coweeman 5 | Description: upstream end of canyon to Goble Creek; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 6 | Description: Goble Creek to unnamed RB trib2; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 7 | Description: unnamed RB trib2 to unnamed LB trib2; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 8 | Description: unnamed LB trib2 to unnamed LB trib3; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Coweeman 9 | Description: unnamed LB trib3 to unnamed RB trib3; Confinement: C; Fish Species present: CH presumed, FC, WS |
| Goble Creek 1 | Description: mouth to north fork Goble Creek; Confinement: C; Fish Species present: WS |
| Goble Creek 2 | Description: north fork Goble Creek to fork; Confinement: Confined; species present: WS known |
| Goble Creek 3 | Description: forks east to extent of steelhead distribution; Confinement: Confined; species present: WS approx. 1.5 miles known, 1.5 miles presumed |
| Goble Creek 4 | Description: forks south to extent of steelhead presence; Confinement: Confined; species present: WS approx. 1 mile known, .25 |

| | **Appendix A: EDT reaches and descriptions** |
|---|---|
| **EDT Reach** | **EDT Reach Description** |
| | miles presumed |
| Jim Watson Creek | Description: mouth to extent of steelhead distribution; Confinement: U to M; Fish Species present: WS presumed |
| LB trib1 (26.0016) | Description: mouth to 0.25 mile up each fork; Confinement: C; Fish Species present: WS presumed |
| LB trib2 (26.0071) | Description: mouth to extent of available habitat; Confinement: M to C; Fish Species present: WS potential |
| LB trib3 (26.0072) | Description: mouth to extent of available habitat; Confinement: M to C; Fish Species present: WS potential |
| LB trib4 (26.0097) | Description: mouth to extent of presumed steelhead distribution; Confinement: C; Fish Species present: WS presumed |
| LB trib5 | Description: mouth to extent of presumed steelhead distribution; Confinement: C to M; Fish Species present: WS presumed |
| LB trib6 | Description: mouth to extent of potential steelhead distribution; Confinement: C to M; Fish Species present: WS—0.6 presumed, 0.7 potential |
| Little Baird Creek | Description: mouth to extent of potential steelhead distribution; Confinement: C; Fish Species present: WS—0.4 known, 0.9 potential |
| Lower Cowlitz-1 | |
| Lower Cowlitz-2 | |
| Martin Creek | Description: mouth to extent of presumed steelhead distribution; Confinement: C; Fish Species present: WS presumed |
| Mulholland Creek 1 | Description: mouth to unnamed RB trib6; Confinement: C; Fish Species present: WS, FC |
| Mulholland Creek 2 | Description: unnamed RB trib6 to unnamed LB trib5; Confinement: C; Fish Species present: WS—1.2 known, 1.9 presumed |
| Mulholland Creek 3 | Description: unnamed LB trib5 to unnamed RB trib7; Confinement: C; Fish Species present: WS—0.1 presumed, 1.4 potential |
| Mulholland Creek 4 | Description: unnamed RB trib7 to end of potential steelhead habitat; Confinement: M to C; Fish Species present: WS potential |
| Nineteen Creek | Description: mouth to extent of presumed steelhead distribution (includes a small RB trib); Confinement: C; Fish Species present: WS presumed |
| North Fork Goble Creek | Description: mouth to extent of steelhead distribution; Confinement: Confined; species present: WS approx. 3 miles known, 1 mile presumed |
| Nye Creek | Description: mouth to extent of steelhead potential; Confinement: M to C; Fish Species present: WS—0.1 presumed, 0.3 potential |
| ONeil Creek | Description: mouth to extent of presumed steelhead distribution; Confinement: C to M; Fish Species present: WS presumed |
| RB trib1 (26.0019) | Description: mouth to RM 0.5; Confinement: M to C; Fish Species present: WS—0.2 presumed, 0.3 potential |
| RB trib2 (26.0068) | Description: mouth to extent of steelhead distribution; Confinement: M to C; Fish Species present: WS—0.3 known, 0.5 presumed |
| RB trib3 (26.0079) | Description: mouth to fork; Confinement: M to C; Fish Species present: WS potential |
| RB trib4 (26.0096) | Description: mouth to extent of presumed steelhead distribution; Confinement: C; Fish Species present: WS presumed |
| RB trib5 (26.0014) | Description: mouth to extent of presumed and potential steelhead distribution; Confinement: C to M; Fish Species present: WS—0.8 presumed, 0.9 potential |
| RB trib6 | Description: mouth to extent of presumed steelhead distribution; Confinement: C to M; Fish Species present: WS presumed |
| RB trib7 | Description: mouth to extent of potential steelhead distribution; Confinement: C; Fish Species present: WS potential |
| Sam Smith Creek | Description: mouth to first road crossing; Confinement: U to M; Fish Species present: WS presumed |
| Skipper Creek | Description: mouth to extent of presumed steelhead distribution (includes both forks); Confinement: M to C; Fish Species present: WS presumed |
| Turner Creek | Description: mouth to extent of steelhead potential; Confinement: M to C; Fish Species present: WS—0.3 known, 2.0 potential |

# E.3. Kalama River

## E.3.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treatment Model (EDT) for the Kalama River. In this project we rated over 40 reaches with 46 environmental attributes per reach for current conditions and another 46 for historical conditions. Over 1,800 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact, less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data for most reaches. However, data is available from Gobar Creek (a Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.3.2. Recommendations

1. Adult chum salmon, Chinook salmon, and steelhead population estimates should continue for the basin. However, more emphasis should be placed on determining the number of hatchery and wild spawners and the reproductive success of hatchery spawners. Summer & winter steelhead and spring Chinook estimates are based on rack counts at Kalama Falls Hatchery (KFH) and are considered accurate and precise. Fall Chinook estimates and chum salmon estimates are based on an assumed observer efficiency and are likely to be less reliable. Coho salmon counts are periodic and not population estimates. Spring Chinook and steelhead escapement estimates should be continued and funding secured to develop accurate and precise adult estimates for chum, Chinook and coho salmon. Smolt population estimates are made for the Kalama basin above KFH for steelhead and spring Chinook using mark-recapture. Currently smolt trapping does not occur in the lower Kalama (<KFH). Funding should be secured to estimate fall Chinook, chum, coho and steelhead juvenile populations in the lower Kalama River. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective.

2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating, as would field surveys.

3. Empirical sediment data was not available for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.
4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Flow monitoring in the mainstem Kalama River was discontinued in the early 1980s. Flow monitoring should be resumed. Bed scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. USFS and USGS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey only a few “representative” mainstem and tributary reaches. In addition, glides and pools were distinguished subjectively and not quantitatively. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves 1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. A combination of Ecology and OSU estimates of Benthic Index of Biological Integrity (B-IBI) collected in the Wind and Cowlitz River basins were used to develop EDT ratings. These estimates should be completed in this and other SW Washington watersheds.
8. Obstructions were not rated and passage was assumed to be 100%. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. These ratings should be updated using SSHIAP database.

## E.3.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This watershed originates from Mount St. Helens. The maximum elevation is approximately 8,300 feet on the summit of Mount St. Helens (USFS, 1996). Kalama Falls (Upper) is a barrier to anadromous fish and is at an elevation of approximately 1250 feet. The Upper Kalama River Watershed Analysis (USFS 1996) indicates the Upper Basin is a transient snow zone and flows are likely influenced by snow-melt and rain-on-snow events. These events influence lower mainstem reaches, but effects are likely masked by tributary flow inputs as one progresses downstream. The Integrated Watershed Assessment (IWA) completed for the Lower Columbia Fish Recovery Board (LCFRB) examines the current condition of key watershed processes by Hydrologic Unit Code (HUC) (LCFRB 2003). IWA results present the percent rain-on-snow area by HUC. EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries (LCFRB 2003). Rain-on-snow percentages range from 0 to 57% for HUCS with associated EDT reaches (Table E7-18). Reaches with percentages >45% were given an EDT rating of 2 (rain-on-snow transitional), and reaches with <45% were given an EDT rating of 3 (rainfall dominated). Natural flow regime ratings were used for both historical and current conditions. Each reaches natural flow regime was used to assign shape patterns when rating other EDT attributes.

**Table E7-18. % Rain-on-Snow Area for HUCs with associated EDT reaches.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC % Rain on Snow Area |
|---|---|---|
| 17080003040201 | K18,19,20,21, Langdon, LakeView Pk | 45 |
| 17080003040202 | North Fork Kalama | 50 |
| 17080003040301 | K11,12,13(.5), Arnold, Unnamed | 14 |
| 17080003040302 | K13(.5),14,15, Jack, Lost | 33 |
| 17080003040303 | K16,17, Bush, Wolf | 57 |
| 17080003040304 | Elk | 50 |
| 17080003040401 | K9,10, Knowlton, Wildhorse | 16 |
| 17080003040402 | Gobar, Bear | 17 |
| 17080003040501 | K1,2,3,4, Spencer, Cedar | 0 |
| 17080003040502 | K5,6, Indian, Lower Falls | 1 |
| 17080003040503 | K7,8, Summers | 7 |
| 17080003040504 | Hatchery Ck | 0 |
| 17080003040505 | Little Kalama, Dee | 8 |

An examination of mean monthly flow data (USGS 2004) from Kalama River gauges supports the above ratings. Mean monthly flow data was plotted for four Kalama River gauge locations: near Cougar, below falls near Cougar, below Italian creek, and near Kalama. Flow patterns were compared to EDT flow patterns for a rainfall dominated watershed and a rain-on-snow transitional watershed. The two uppermost gauges (near Cougar and below falls near Cougar) show evidence of rain-on-snow effects with high winter flows and increased flows through late spring. The two lower gauges (below Italian Ck. and near Kalama) show a clear rainfall dominated pattern with high winter flows decreasing steadily through the spring into summer.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watershed does not have artificial flow regulation, and was given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Direct measures of interannual high flow variation are not available for most basins. USFS has conducted watershed analysis in the EF Lewis, NF Lewis, Wind, White Salmon, Washougal, Kalama, Cowlitz, and Cispus Rivers and Rock Creek (USFS 1995a, USFS 1995b, USFS 1996a, USFS 1996b, USFS 2000). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis pertains to vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-19. For watersheds in which the two-year peak flow (Q2yr) increases 10% the EDT rating is 2.25. For increases of 20% the EDT rating is 2.5. Data for the Upper Kalama Basin indicated an increase in peak flow of 5 to >10% (Table E7-19). We assumed a 10% increase would be representative of the upper basin. Q2yr analysis of peak flow data (using EDT manual protocol) for USGS gauge data (2004) on the Kalama River below the lower falls (1934-1977) indicated a peak flow increase of 17% (EDT rating ~ 2.4). Upper and lower basin ratings were averaged and an EDT rating of 2.3 was assigned for all reaches.

**Table E7-19**. **Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10 -12% |
| Rock Cr | | 1 -5% |
| Upper Kalama | | 5 - >10% |
| Cispus | | <10% |

*Level of Proof*— Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*— By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Research on the effects of land use practices on summer low flow is inconclusive. Therefore, template and current conditions were rated the same (EDT rating of 2), except where noted.

The LCFRB Level 1 Technical Assessment Final Report for WRIAS 27&28 (2001) presents water usage by category for the Kalama watershed. Total water usage is estimated at 427 million gallons annually for city water, agriculture, industry, and domestic wells. The largest purveyor is the City of Kalama, which serves a population of 3500 and has approximately 1500 water hook-ups. Estimated water usage for the month of August by the City is 31 million gallons. This translates to an average withdrawal of approximately 1.5 cfs. Hatchery withdrawals occur in Kalama 6 for use at the Kalama Falls Hatchery

(KFH), in Kalama 4 and Hatchery Creek for the Fallert Creek Hatchery, and in Gobar Creek for the Gobar acclimation ponds. All water pumped for hatchery usage is returned to the stream at the lower end of the facility/pond. Of these facilities, KFH pumps the most water in August with withdrawals ranging from 9 to 13 cfs (pers. com. Steve Gross WDFW).

Using USGS gauge data, the average flow for the Kalama River in August was calculated. Flows ranged from 263 cfs (measured near Kalama for years 1911-1932) to 310 cfs (measured below Italian Creek for years 1948-1980). The Kalama is atypical of most SW Washington watersheds in that there are many sources of groundwater input, which buffer the effects of hot, dry summers. Low flows are less extreme and more consistent than most SW Washington streams. Withdrawals from the aforementioned facilities were found to be minimal when compared to mean August flows. The Washington State Conservation Commission Limiting Factors Analysis (LFA) for WRIA 27 also notes that "withdrawals are not considered a major concern within the Kalama basin today; however… could become a problem in the near future" (Wade 2000). Low Flow EDT ratings for reaches with these withdrawals were not adjusted.

Flows in the lower 0.1 miles of Hatchery creek are increased in the summer months, due to the release of hatchery-use water pumped from the mainstem Kalama River into the creek. The intake on Hatchery Creek itself is only used December through March and does not impact summer low flows (pers. com. Steve Gross WDFW). This reach was given an EDT rating of 1.9.

The NF Kalama River and Langdon, Jacks, and Wolf Creeks are noted in the LFA for WRIA 27 (Wade 2000) as having potential low flow problems with flows going subsurface. However, these problems are attributed to sediment/gravel accumulation at the mouth rather than from a reduction in flow. EDT ratings of 2 were given for these reaches.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Flow – Intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. This attribute was given an EDT rating of 0 for current conditions due to the lack of storm water runoff and hydroelectric development in the watershed. There are no major metropolitan areas in this watershed with large areas of impervious surfaces.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in this watershed. Based on USFS watershed analyses and a Q2yr analysis, we assumed a 13% increase in peak high flows. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in interannual variability in high flows (pers. com. Lestelle, Mobrand Biometrics, Inc). Ratings for interannual variability in high flow were translated directly into ratings for intra-annual flow.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. Stream length was assumed to be the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*— Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. In addition, VanderPloeg and Grobelny (pers. com.) took spot measurements of wetted widths at summertime low flow levels in many Kalama EDT reach segments during the year 2000 for use by SSHIAP. Where there was overlap, spot measurements taken in 2000 were compared with representative reaches surveyed in 2002, and were found to be similar. To determine if surveys were conducted during average low flow conditions, streamflows corresponding to survey dates from both these data sources were compared to mean August flows (for all available years). USGS (2004) streamflow data is not available for the Kalama River in 2000 and 2002, however, gauge data from the South Fork (SF) Toutle River (near Toutle, WA) and East Fork (EF) Lewis River (near Heisson, WA) were assumed to be good surrogates for identifying fluctuations in streamflow caused by rain events. Mean August streamflow for the SF Toutle (1940-2002) was 118 cfs (range: 79 to 172 cfs), and flows corresponding to 2000 and 2002 survey dates ranged from 69 to 159 cfs (USGS 2004). Mean August streamflow for the EF Lewis (1930-2002) was 83 cfs (range 44 to 278 cfs), and flows corresponding to 2000 and 2002 survey dates ranged from 48 to 121 cfs (USGS 2004). It was assumed conditions on the Kalama River were similar indicating surveys were conducted during near average low flow conditions.

Where representative reach data (VanderPloeg 2003) was available, it was used in rating the corresponding EDT reaches. For other reaches, spot measurement data from 2000 was used when available. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys and/or spot measurement reaches with similar habitat, gradient and confinement (Table E7-20).

Spot measurements for Hatchery Creek were taken below the hatchery, where water pumped from the Kalama River for hatchery use is returned. Current widths in this area are likely increased from the supplemental flow and are not representative of the entire reach. The measured width was divided by two in order to develop an EDT value for this reach. Hydroconfinement in Kalama 1 was not thought to significantly reduce minimum wetted widths. No adjustments were made for this reach.

**Table E7-20. Reference reaches used for reaches not surveyed for minimum wetted widths.**

| Non-surveyed Reach | Reference reach |
|---|---|
| Indian Creek | Spencer Creek – spot measurement |
| Unnamed Cr (27.0087) | Spencer Creek – spot measurement |
| LakeView Peak Ck | Langdon Creek – spot measurement |
| Kalama 6 | Kalama 5 – representative reach |
| Kalama 7 | Kalama 5 – representative reach |
| Kalama 10 | Kalama 11 – representative reach |
| Kalama 12 | Kalama 11 – representative reach |
| Kalama 15 | Kalama 14 - representative reach |
| Kalama 16 | Kalama 17 – representative reach |
| Kalama 20 | Kalama 21 – spot measurement |
| Kalama 18 | Avg of 2 spot measurements in Kalama 18 |

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in lower Columbia River tributaries were surveyed by Steve VanderPloeg (WDFW) in 2003. Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). To determine if surveys were conducted during average high flow conditions, streamflows corresponding to survey dates were compared to mean January flows (for all available years). USGS (2004) streamflow data is not available for the Kalama River in 2000 and 2002, however, gauge data from the South Fork (SF) Toutle River (near Toutle, WA) and East Fork (EF)

Lewis River (near Heisson, WA) were assumed to be good surrogates for identifying fluctuations in streamflow caused by rain events. Mean January streamflow for the SF Toutle (1940-2002) was 1031 cfs (range: 318 to 2488 cfs), and flow corresponding to the 2003 survey date was 1090 cfs (USGS 2004). Mean January streamflow for the EF Lewis (1930-2002) was 1407 cfs (range: 303 to 3459 cfs), and flow corresponding to the 2003 survey date was 2170 cfs (USGS 2004). SF Toutle flows were at average levels, while EF Lewis flows were higher than average. It was assumed conditions on the Kalama River fell somewhere between these two levels, indicating surveys were conducted during near average or slightly higher flow conditions. Wetted widths recorded during these surveys were used without adjustment, realizing they may be biased slightly high.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. The percent increase between low and high flow widths for all subbasins was compared to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data (EDT reach Kalama 14). A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Using only Kalama mainstem reach data (EDT reaches Kalama 2,5,11,17) the mean increase in stream width is 30%. A possible explanation for this is that most of the Lower Kalama watershed is currently confined. Mainstem EDT reaches from Wolf Creek to Spencer Creek (Kalama 4-17) run through natural canyons. Lower EDT reaches (Kalama 1-3) were historically unconfined or moderately confined, but are currently heavily diked and channelized. Mainstem reaches from Wolf Creek to the Upper Falls are generally moderately confined with little or no hydroconfinement.

Therefore, actual “wetted width-high” values were used in reaches where data was available (except Kalama 14). For reaches without high flow width data, a 1.3 multiplier (30%) was used to expand “wetted width-low” data in confined (or hydro-confined) mainstem reaches (Kalama 1 – 17) and a 1.6 multiplier (60%) was used to expand “wetted width-low” values for all tributary and moderately confined mainstem reaches (Kalama 18-21). Unconfined reaches of the Lower Kalama (Kalama 1 & 3) are currently heavily diked and channelized. In the historic condition these areas were likely more braided and wider during winter flows. To develop historic "wetted width-high" values, a 2.0 multiplier was used for Kalama 1 and a 1.6 multiplier was used for Kalama 3 to expand current "wetted width-low" values for these reaches. Kalama 2 is moderately confined and current width values for this reach were used for historic ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as % gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003. Confinement ratings were estimated during these surveys (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps (1:24,000) were consulted (via GIS) to verify and/or adjust ratings. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4 (Table E7-21). There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings.

**Table E7-21**. **Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures and activity) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. Most hydro-modification consists of roads in the floodplain and diking. The SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, USGS topography maps (1:24,000 via GIS), and WRIA 26 LFA (Wade 2000) were reviewed and professional judgment was used to assign EDT ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools*. Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, it was assumed that for historical conditions the percentage of pools was significantly higher than for current conditions. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, pool habitat was estimated to be 40% and 30% respectively (WFPB 1994). Tailouts were assumed to represent 15-20% of pool habitat, which is the current range from WDFW surveys (VanderPloeg 2003). Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data (VanderPloeg 2003) indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

Representative reaches of lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Surveys primarily followed USFS stream survey level 2 protocols, which delineate between riffles and slow water, but not pools and glides. Glide habitat is the most difficult habitat to identify, and, therefore, was estimated but not surveyed. In general, WDFW survey methodology did not appear to work for glides. Therefore, Wind River data (USGS) was examined to help differentiate between these two habitat types. Wind River data showed a positive relationship between gradient and/or confinement and riffle habitat. It also showed a negative relationship between pool habitat and gradient and/or confinement. However, there was no relationship between pools and glides. There was variation between surveyors when the same reach was walked. This may be due to habitat changes but it could also be due to measurement error between surveyors. In general, glides accounted for 30% to 50% of the non-riffle habitat. For the Kalama River, glide habitat estimated during habitat surveys averaged 38.3% of non-riffle habitat (range: 30.7% to 79.8%), with only one surveyed reach greater than 50%. Glide habitat in Kalama-14 was estimated at 79.8% of non-riffle habitat. This reach is known, from WDFW snorkel surveys, to have fewer pools and more riffle/glide habitat. Based on comparison with Wind River data, Kalama River glide percentage estimates seemed reasonable and were not adjusted. Assumptions about glide and pool habitat are most likely to affect coho salmon since they prefer pool habitat during their extended freshwater rearing.

For the Kalama River, habitat surveys (VanderPloeg 2003) were conducted within EDT reaches Kalama 2, 5, 11, 14, 17, and Gobar Creek. Data from these surveys and professional knowledge were used to develop ratings for EDT reaches within the watershed based on areas of similar habitat, confinement and gradient. Table E7-22 lists the reference reaches surveyed and the EDT reaches data was applied to.

**Table E7-22. Reference reaches used to develop ratings for similar reaches.**

| Surveyed Reference Reach(s) | Data applied to EDT Reach: |
|---|---|
| Kalama 2 | Kalama 1 (adjusted for tidal) & 2 |
| Kalama 5 | Kalama 3,4&5 |
| Kalama 11 | Kalama 6-11 |
| Kalama 11 & 14 (Average) | Kalama 12-14 |
| Kalama 11,14,&17 (Average) | Kalama 15-21 |
| Gobar Creek | Tributaries <2% Gradient |
| Gobar Ck, NF Elochoman-3 (Average) | Tributaries >2% - <5% |
| NF Elochoman-3 | Tributaries >5% |

EDT reach Kalama-1 is tidal from the mouth to the Camp Kalama area; this area was classified as a glide. Ratings for this reach were generated from Kalama-2 ratings by decreasing the percentage of pool and small-cobble riffle habitat and increasing the glide habitat accordingly. Based on similarities in habitat, confinement and gradient, survey data from Kalama-5 and Kalama-11 was used to rate reaches Kalama 3-5 and Kalama 6-11, respectively. Survey data from Kalama 11 and 14 was averaged to generate ratings for reaches Kalama 12-14, while data from surveys in Kalama 11, 14 & 17 was averaged to rate reaches Kalama 15-21.

Habitat survey data for Kalama River tributaries is lacking. Gobar Creek has a gradient <2% and was the only Kalama River tributary surveyed. Survey data from within the reach indicated tailouts comprised 1.3% of habitat, while pools comprised 49.8%. Based on professional knowledge of Gobar Creek, the ratio of tailouts to pools in the surveyed area appeared to be low, and was not felt to be representative of the entire creek. This may be the result of not surveying a large enough area to be truly representative of the reach, or attributable to surveyor discrepancy in identifying where a pool ends and a tailout starts. Tailouts were assumed to be 25% of pool habitat, and ratings were adjusted accordingly. Adjusted Gobar Creek data was applied to tributaries with gradients <2%, of which Spencer Creek was the only one. Of all the representative stream segments surveyed by VanderPloeg (2003), the survey conducted in EDT reach North Fork (NF) Elochoman-3 had the highest gradient at 3.33%. Due to a lack of other information, NF Elochoman-3 habitat composition data was applied to Kalama River tributaries with gradients >5%. The average of Gobar Creek and NF Elochoman-3 data was applied to Kalama River tributaries with gradients between 2 and 5%.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. Most of the Kalama basin is confined with some areas of moderate confinement. An EDT rating of 0% off-channel was assigned to moderately confined/confined reaches. Only the lowest reach is completely unconfined (Kalalma1-tidal). For the historic condition, this reach was given an EDT rating of 20% off-channel habitat. Currently, this reach is diked and channelized and has little if any off-channel habitat (~1%). Moderately unconfined reaches (portions of Kalama 2 & 3) likely had some off-channel habitat, but currently have very little to none due to hydroconfinement.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations and expert opinion were used and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— Currently, only one barrier reach is identified in the Kalama Basin EDT model – Lower Kalama Falls. Lower Kalama Falls was an historic barrier to some anadromous species at various life stages. Modifications to the falls (i.e. fish ladder & jump curtain) have affected passability in the current condition. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for this barrier. Most tributaries are represented in the EDT model by a single reach. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon are more impacted by barriers, due to their preference for spawning in small tributaries. As barrier inventories become more complete and available for the Kalama Basin it would be valuable to incorporate these into the EDT model.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. By definition, all reaches were given an EDT rating of 0 for the historical condition.

Mainstem EDT reaches above Summers Creek are behind closed gates on private lands managed for timber harvest. Tributary reaches above the lower falls are sparsely populated and/or on private lands managed for timber harvest. Withdrawals in these areas are thought to be minimal or non-existent, and were given an EDT rating of 0. The LCFRB Level 1 Technical Assessment Final Report for WRIAS 27&28 (2001) presents water usage by category for the Kalama watershed. Total water usage is estimated at 427 million gallons annually for City water, agriculture, industry, and domestic wells. Most occurs in Kalama1 & 2. The majority of this is pumped as groundwater from pipes or wells under or near the river itself and screening is not an issue. The City of Kalama water withdrawal facility is at the lower end of Kalama 2. Kalama 1 & 2 were given EDT ratings of 1.5 and 2, respectively. Reaches with low gradient, unconfined areas (i.e. farmland) and/or reaches with dwellings built next to the stream were given an EDT rating of 0.1 to account for occasional withdrawals (K3,5,7,&8).

The Kalama Falls hatchery has a screened intake in the mainstem Kalama at the lower end of Kalama 6. This intake operates year round. The Fallert creek hatchery has two intakes, one on Hatchery (Fallert) Creek and the other on the mainstem Kalama at the lower end of Kalama 4, both are screened. The mainstem intake operates year round, while the Hatchery Ck. intake operates only December through March when water is available to supplement the Kalama River intake. Gobar creek has a gravity fed intake that feeds the Gobar acclimation ponds. This intake runs year round and is screened (pers. com. Gross, WDFW). Kalama 6 was given an EDT rating of 2, while Kalama 4, Gobar Ck. and Hatchery Ck. were given a rating of 1.

*Level of Proof*—A combination of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table developed by Dan Rawding (WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings.  The table is based on professional judgment.  It relates bed scour to confinement, wetted width (high flow), and gradient and assumes scour increases as gradient and confinement increase.  In Kalama –1 tidal, where scour likely occurred during low tides and high flow events, the pristine look-up table rating was reduced by ½.

Historic EDT ratings were developed and used as the baseline for scour in the current condition.  Template ratings for bed scour were increased as follows:  it was assumed increases in peak flow and hydroconfinement also increased bed scour, and scour ratings were increased 0.049 for each tenth (0.1) of increase in the EDT peak flow rating and for each point (1.0) increase in the hydroconfinement rating.  In Kalama 1-tidal, where the reach is currently slough-like (mud bottom) for much of the reach, bed scour was rated by reducing the current look-up table rating by ½.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term.  It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—Most Lower Kalama EDT reaches are rainfall dominated.  Mainstem EDT reaches above Elk Creek and associated tributaries were rated as rain-on-snow transitional.  Anchor ice and major icing events are rare or non-existent.  EDT ratings of 0 were assigned to all reaches in the historical and current condition.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

For current conditions, riparian zones with mature conifers are rated at 1.0.  Riparian zones with saplings and primarily deciduous trees are rated as 1.5 due to lack of shade and bank stability.  Riparian zones with brush and few trees are rated as 2.  For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone.  Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better.  Most current vegetated riparian zones with no hydroconfinement should be rated as a 1 to 1.5.  When vegetation is lacking and/or hydroconfinement/residential development exists, riparian ratings were increased based upon the severity of each.

Information on the status of riparian zones in the Kalama watershed was compiled from: the LFA for WRIA 27 (Wade 2000), EDT Habitat Surveys by WDFW (VanderPloeg 2003), the SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000 via GIS).  Most of the Kalama River Watershed (~96%) is managed for timber harvest by private timber companies, and was logged heavily from 1960-1980 (Wade 2000).  The LFA for WRIA 27 indicates 85 miles out of 97.25 miles of anadromous habitat on the Kalama has "poor" riparian conditions.  "TAG [Technical Advisory Group] noted that Wildhorse Creek, North Fork Kalama, Gobar Creek, Lakeview Peak Creek, and Arnold Creek, historically the most productive steelhead streams, have particularly "poor" riparian conditions."  A rating of “poor” was defined as riparian areas with vegetation lacking and/or mostly deciduous species (Wade 2000). WDFW habitat surveys (VanderPloeg 2003) were conducted in EDT reaches Kalama 2, 5, 11, 14, 17 and Gobar Creek. Notes on riparian composition were taken as part of these surveys. Most reaches had a mix of alder, big-leaf maple, Douglas fir, cedar, and hemlock at various stages of growth. While all mainstem areas surveyed had conifers within the reach, stands of old/mature conifers were noted as being sporadic. Gobar Creek was noted as having alders as the dominant species with young big-leaf maples and Douglas fir also present.

Reaches Kalama 1, 2, 3 & 4 have varying degrees of hydroconfinement, and residential development adjacent to the stream. These reaches were given EDT values for riparian function of 3, 1.5, 2, & 1.5, respectively. Kalama 5 is in a steep, naturally-confined canyon with abundant mature conifers throughout the majority of the reach, and was given a value of 0.5. The NF Kalama and Arnold, Gobar, Lakeview Peak, & Wildhorse Creeks were given a value of 1.5. All other reaches were given a value of 1.

*Level of Proof*— There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—In general, the template condition for wood in Lower Columbia River tributaries was assumed to be at an EDT rating of 0 for all areas except large canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind Rivers, which likely did not hold LWD as well. These areas were assumed to be at a rating of 1 to 2, based on the width/length of the canyon. For the Kalama watershed, mainstem canyon reaches Kalama 4, 5 and 7-16 were given an EDT rating of 1 for the template condition. All other reaches were given an EDT rating of 0.

LWD counts were made during WDFW Habitat surveys (VanderPloeg 2003) in EDT reaches Kalama 2, 5, 11,14, 17 & Gobar Creek using EDT protocol. All mainstem counts translated into an EDT rating of 4, the Gobar Creek count translated into an EDT rating of 3. Due to large boulder habitat present in the mainstem canyon reaches, LWD ratings were changed to 3 for Kalama 4, 5 and 7-16. It was felt large boulder habitat acts as a partial surrogate for LWD in these areas. All other mainstem reaches were given a rating of 4. Medium sized tributaries (>35 ft ww-high), such as Gobar Creek were given a rating of 3. LWD surveys in Mill Germany, and Abernathy Creek watersheds (LCFRB 2003) indicated, on average, small tributaries (<35 feet ww-high) are at an EDT rating of 2 under current conditions. A rating of 2 was applied to small tributaries of the Kalama River.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate the percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) examined the relationship between road density and fine sediment levels in coastal watersheds of Washington State's Olympic Peninsula region, and found that as road density increased by 1 $km/km^2$ fine sediment levels increased by 4.3% (2.65% per 1 $mi./mi.^2$) However, Duncan and Ward (1985) found a lower increase in percentage of fines in southwest Washington, but attributed much of the variation in fines to different soil types. The Wind River is a Lower Columbia River tributary located in SW Washington and is likely representative of other watersheds in the region. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 $mi/mi^2$ of roads for all watersheds ($R^2 = 0.31$, n=17). The increase was 1.52% per 1 $mi/mi^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored, was excluded. Rather than use all three years of Layout Creek data, only the median was used and the final relationship used for EDT was a 1.34% increase in fines per 1 $mi/mi^2$ ($R^2$=0.56, n=15) (Figure E7-2).

Kalama River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries. Table E7-23 presents IWA road density by HUC for HUCs with associated EDT reaches. An exception to this is the tidal reach of the Kalama (Kalama-1), which is currently heavily diked and slough-like. This reach was given an EDT rating of 4 for the current conditions.

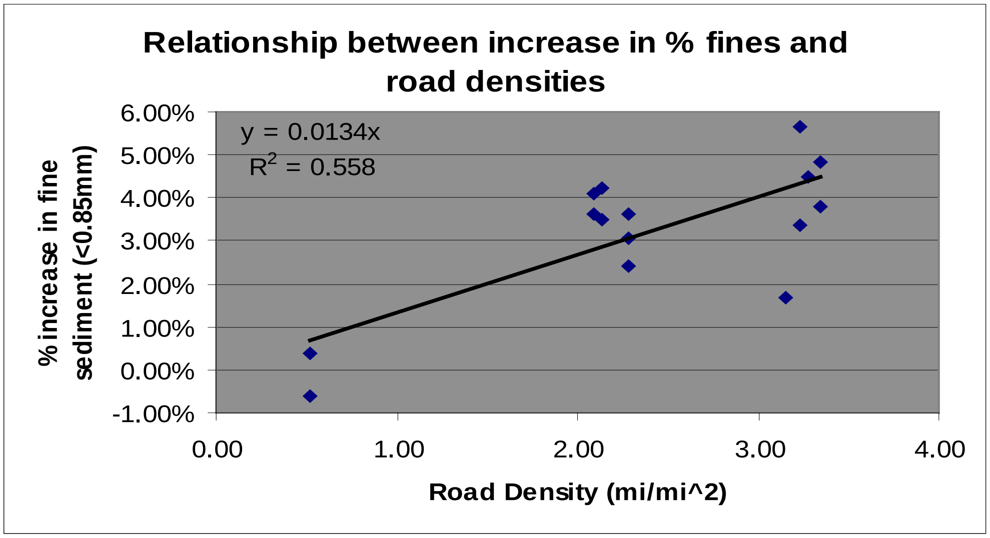


**Figure E7-2.** **Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

**Table E7-23.** **IWA Road Densities for HUCS with Associated EDT Reaches and EDT ratings for Fine sediment.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Fines Rating |
|---|---|---|---|
| 17080003040201 | K18,19,20,21, Langdon, LakeView Pk | 6 | 2.15 |
| 17080003040202 | North Fork Kalama | 6.1 | 2.15 |
| 17080003040301 | K11,12,13(.5), Arnold, Unnamed | 6.6 | 2.25 |
| 17080003040302 | K13(.5),14,15, Jack, Lost | 6.6 | 2.25 |
| 17080003040303 | K16,17, Bush, Wolf | 6.4 | 2.25 |
| 17080003040304 | Elk | 5.9 | 2.15 |
| 17080003040401 | K9,10, Knowlton, Wildhorse | 5.5 | 2.1 |
| 17080003040402 | Gobar, Bear | 7.4 | 2.5 |
| 17080003040501 | K1,2,3,4, Spencer, Cedar | 6.1 | 2.15 |
| 17080003040502 | K5,6, Indian, Lower Falls | 5.5 | 2.1 |
| 17080003040503 | K7,8, Summers | 6.6 | 2.25 |
| 17080003040504 | Hatchery Ck | 6.5 | 2.25 |
| 17080003040505 | Little Kalama, Dee | 5.1 | 2.05 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In rating this attribute it was assumed that percent embeddedness is directly related to the percentage of fines in spawning gravel.

In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), it was assumed embeddedness was less than 10%, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2.

Using the USFS Wind River data and analysis described above for rating fine sediment, a scale was developed relating road density to percent embeddedness. This scale was used to generate embeddedness ratings for all EDT reaches in the watershed. An exception to this is the tidal reach of the Kalama (Kalama-1), which is currently heavily diked and slough-like. This reach was given an EDT rating of 3 for the current conditions.

Kalama River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries. Table E7-24 presents IWA road density by HUC for HUCs with associated EDT reaches.

**Table E7-24. IWA Road Densities for HUCS with Associated EDT Reaches and EDT ratings for Embeddedness.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Emb. Rating |
|---|---|---|---|
| 17080003040201 | K18,19,20,21, Langdon, LakeView Pk | 6 | 0.86 |
| 17080003040202 | North Fork Kalama | 6.1 | 0.86 |
| 17080003040301 | K11,12,13(.5), Arnold, Unnamed | 6.6 | 0.9 |
| 17080003040302 | K13(.5),14,15, Jack, Lost | 6.6 | 0.9 |
| 17080003040303 | K16,17, Bush, Wolf | 6.4 | 0.9 |
| 17080003040304 | Elk | 5.9 | 0.86 |
| 17080003040401 | K9,10, Knowlton, Wildhorse | 5.5 | 0.83 |
| 17080003040402 | Gobar, Bear | 7.4 | 1 |
| 17080003040501 | K1,2,3,4, Spencer, Cedar | 6.1 | 0.86 |
| 17080003040502 | K5,6, Indian, Lower Falls | 5.5 | 0.83 |
| 17080003040503 | K7,8, Summers | 6.6 | 0.9 |
| 17080003040504 | Hatchery Ck | 6.5 | 0.9 |
| 17080003040505 | Little Kalama, Dee | 5.1 | 0.8 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: SEV = a + b(lnX) + c(lnY) , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*— Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process that occasionally increased turbidity after an extensive hot burn. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels at an EDT rating of 0 in small tributaries (<35 ft. ww-high), 0.3 in medium tributaries (>35 ft. ww-high), and 0.5 in mainstem reaches.

Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (2004). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout Creek, Panther Creek, and the Middle Wind are over 40 mg/L, and other basins are 5-40mg/L with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If suspended sediment levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L levels last 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support EDT ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for lower mainstem reaches.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Historical temperatures are unknown the in the Kalama River subbasin. The only historical temperature data that was located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary processes transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2000). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches can be estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next it was assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, 49 meters was used as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, the relationship between forest angle and percentage of shade was used (WFPB 1997 Appendix G-33). Finally, the relationship between elevation, percentage of shade and the maximum daily stream temperature was used to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams, our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. A correction factor was developed for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

For current conditions, the EDT maximum temperature calculator (MS Access) provided by Mobrand Biometrics, Inc. (MBI) was used to generate ratings for reaches where temperature data was available. Temperature data corresponding to summertime low flows (August) was limited for the Kalama River watershed. Table E7-25 lists the EDT reaches where temperature data was available and the data source. Temperature data collected within an EDT reach was assumed to be representative of the entire reach and was used to generate an EDT rating for the reach. Ratings for mainstem reaches without temperature data were extrapolated based on elevation, and proximity to reaches with temperature data.

**Table E7-25. Kalama River EDT reaches with August temperature data & data source.**

| EDT Reach | Temperature Data Source |
|---|---|
| Kalama 1-tidal | Kalama Gauge @ Kalama 2001 & 2002 (USGS 2004) |
| Kalama 3 (top) | Fallert Creek Hatchery Intake 1984- 2003 (WDFW) |
| Kalama 5 (top) | Kalama Falls Hatchery Intake 1984-2003 (WDFW) |

Temperature data was not available for Kalama River tributaries and reaches above Lower Kalama Falls (>Kalama 6). The Kalama River has several areas of significant groundwater input in the upper watershed that keep mainstem, summertime temperatures colder than most other Southwest Washington tributaries. Reach elevations, location of groundwater inputs, and expert opinion were used to generate maximum temperature ratings for EDT reaches Kalama 7-21. All tributary reaches were assigned an EDT rating of 2.0.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Minimum temperature data was lacking in the basin. Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) –5.8305 ( $R^2$= 0.32, n=27). This relationship was used to generate categorical ratings (Table E7-26) based on elevation.

**Table E7-26. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

Minimum temperature ratings were assigned to both the historical and current conditions. Tributary ratings were assigned based on the elevation at the mouth unless they have more than one reach. In this case, elevations within each reach were used. Based on the elevation model, ratings for reach Kalama 21 should be a 2, however, spring water influence in this area is believed to keep this reach at a rating of 1.

*Level of Proof*— A combination of expanded empirical observations, derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

## Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Significant Sources of groundwater input are known to occur from springs just below the Upper Falls in Kalama 21, and from Pigeon Springs in lower portions of Gobar Creek and upper portions of Kalama 10. Kalama 10 and 21 were given an EDT rating of 0 for the historic and current conditions. Upper portions of Gobar Creek are likely unaffected by Pigeon Springs, while lower portions are heavily affected. Gobar Creek was given an EDT rating of 1 for historic and current conditions. Effects from these groundwater inputs likely influence downstream reaches, but the extent of these effects are unknown. Reaches immediately downstream (Kalama 9 & 20) were given an EDT rating of 1 for historic and current conditions. All other reaches were rated using the following guidelines. Historically, there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries in the upper watershed likely had less groundwater input. These reaches were given an EDT rating of 2. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*— A combination of empirical observations, derived information, and expert opinion was used to estimate the historic and current ratings for this attribute in reaches with known sources of significant groundwater input and the level of proof has a strong weight of evidence in support but not fully conclusive.

Expert opinion was used to estimate the current and historical ratings for this attribute in all other reaches and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*— Alkalinity was estimated from historical USGS data for conductivity (USGS 2004) on the Elochoman, Washougal, Wind, Kalama, and Lewis Rivers using the formula: Alkalinity =0.421 *Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. The mean July to September flow was used to determine the mean alkalinity values. For basins without flow data we used mean summer alkalinity values. For the Kalama River alkalinity was calculated as 17.27 mg/l and adjusted for flow, resulting in 22 mg/l, for an EDT rating of 1.9. This rating was applied to all reaches. Alkalinity in the historic condition was given the same rating as the current condition for all reaches.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired, an EDT rating of 0 (>8mg/l in August). Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All reaches of the Kalama were assumed to have greater than 8mg/l of dissolved oxygen, except for Kalama 1-tidal. The lower portions of Kalama 1 are slough-like/tidal. Segments of the lower Kalama are 303-d listed due to excessive water temperature by the Washington Department of Ecology, and a shallow water sand bar at the mouth has been identified as a potential thermal barrier to fish migration during summer low flows (Wade 2000). This area may experience less than optimal dissolved oxygen levels during summer low flows. Kalama 1-tidal was given an EDT rating of 1.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. There is more uncertainty in the ratings for reaches with sloughs or slough-like conditions, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because, of the lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically, nutrient enrichment did not occur because, by definition, watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches under current conditions the following factors were examined: fertilizing by timber companies, reaches downstream from fish hatcheries, agriculture effects, septic tanks, and storm water run-off.

Most of the Kalama River Basin above Lower Kalama Falls (>Kalama 5) is owned by Weyerhaeuser and managed for timber harvest as part of the Mount St. Helens South Tree Farm. Stream adjacent homes in this area are rare. Weyerhaeuser utilizes the following protocol for fertilizing the Mount St. Helens North and South Tree Farms (pers. com. Byron Richert, Weyerhaeuser): fertilizer is applied aerially (via helicopter), the fertilizer used is Urea 46-00-0 applied at 440 lbs./acre (210 lbs. active Nitrogen), only Douglas Fir responsive stands (>50% Douglas Fir) are fertilized, fertilization starts at age 18 and is conducted once every seven years until three years before harvest. The effects of this fertilization on stream enrichment are likely difficult to measure, but were assumed to be minimal. All mainstem and tributary reaches (except Gobar Creek) from EDT reach Kalama 6 upstream were given an EDT rating of 0.

The WDFW Kalama Falls Hatchery is located at the top of EDT reach Kalama 5 and the WDFW Fallert Creek Hatchery is located on the lower portion of Fallert (Hatchery) Creek, which enters the Kalama at the top of EDT reach Kalama 3. A WDFW hatchery acclimation pond is operated on Gobar Creek. Some nutrient enrichment likely occurs from hatchery operations. Most other enrichment likely occurs from stream adjacent homes along the mainstem and tributary reaches of the lower Kalama River (<Kalama 6) via septic systems and small-scale agriculture. Industry operations in the historic floodplain below Interstate-5 (Kalama 1-tidal) may contribute to increased enrichment. EDT reaches Kalama 2-5, Gobar Creek and Fallert (Hatchery) Creek were given an EDT rating of 1. Kalama 1-tidal was given a rating of 1.5.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds. Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness in SW Washington watersheds was estimated from direct observation (stream surveys, snorkel surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, local knowledge, and expert opinion. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer, which was captured in the EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Abernathy, Germany, and Mill creeks (pers. com. Hanratty, WDFW), smolt trapping activities on the Kalama River above Lower Kalama Falls (pers. com. Wagemann WDFW), (3) electro-shocking in 2002 by USFWS in Abernathy Creek (pers. com. Zydlewski, USFWS), (4) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (5) WDFW stream & snorkel surveys on the Elochoman (pers. com. Byrne, WDFW), Kalama, East Fork Lewis, Toutle and Coweeman Rivers, (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls).

The tidal reach of the lower Kalama River (Kalama 1-tidal) likely has many species present from the Lower Columbia River. An estimated 30+ species were included in this list: Chinook, chum, coho, steelhead/rainbow trout, cutthroat trout, sculpin sp.(3) (torrent, coastrange, reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback, and dace. Most of the non-native fish species likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW). For EDT reaches Kalama 2-5, Chinook, chum, coho, steelhead/rainbow trout, cutthroat trout, sculpin sp.(3), largescale sucker, peamouth, northern pikeminnow, 3-spine stickleback, and Eastern banded Killifish were assumed to be present. Above Lower Kalama Falls (Kalama 6-21 and tributaries), only steelhead/rainbow trout, cutthroat trout, sculpin sp.(2) and spring Chinook were assumed to be present. Tributaries below Lower Kalama Falls were assumed to have these species as well as coho.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. Introduced species ratings were derived from current fish species richness data (see Fish Community Richness above). Kalama 1-tidal is the reach most likely to harbor introduced species. The Eastern banded killifish is the only non-native species documented to penetrate into higher reaches of SW Washington watersheds.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

The WDFW Kalama Falls Hatchery (located at the top of EDT reach Kalama 5) and the WDFW Fallert Creek Hatchery (located at the lower end of Fallert (Hatchery) Creek) combine to release early/late coho, fall Chinook, and summer/winter steelhead, annually. In addition, a WDFW acclimation pond on Gobar Creek, which enters the Kalama in EDT reach Kalama 10, is used to acclimate summer/winter steelhead and spring Chinook (pers. com. Castenada, WDFW). Wild summer steelhead broodstock scatter plants are made in several areas above Lower Kalama Falls (pers. com. Wagemann, WDFW), but were not included in developing EDT ratings.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency.

EDT reaches Kalama 1-5 and Fallert (Hatchery) Creek were given an EDT rating of 4. Gobar Creek and Kalama 10 were given a rating of 3. Kalama 6-9 were given a rating of 2. All other reaches were rated at 0.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants and pathogen levels were assumed to be at background levels. All reaches were given an EDT rating of 0.

The WDFW Fallert Creek Hatchery is located at the downstream end of Fallert (Hatchery) Creek, which enters the Kalama in EDT reach Kalama 3. The WDFW Kalama Falls Hatchery is located at the top of Kalama 5. EDT reaches Kalama 3-6 and Fallert (Hatchery) Creek were given an EDT rating of 3. A WDFW acclimation pond is located in Gobar Creek, which enters the Kalama at the top end of EDT reach Kalama 10. Reaches Kalama 1, 2, 7-11, and Gobar Creek were given an EDT rating of 2. All other reaches were rated at 0.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

***Rationale*—** In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

Utilizing GIS, the SSHIAP and DNR roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000) were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use; a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; a rating of 2 was given to reaches with multiple access points (or road parallels reach) through public lands or unrestricted access through private lands; a rating of 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands; and a rating of 0 was given to reaches far from population centers with no roads.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition.

The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species (i.e. birds) is unknown in this watershed.

The WDFW Kalama Falls and Fallert Creek Hatcheries release early/late coho, fall Chinook and summer/winter steelhead. Steelhead and spring Chinook are also acclimated and released on Gobar Creek. Hatchery releases potentially increase predation on native fish. Populations of non-native piscivorous fish from the Lower Columbia River are known to exist in the tidal reach of the Kalama River, although the exact number of these species and their distribution has not been documented. EDT reaches Kalama 1-5, Gobar and Fallert (Hatchery) Creeks were given increased ratings for predation. All other reaches were given an EDT rating of 2.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Mainstem reaches with historic chum presence (spawning) were given a rating of 0 (super abundant, >800). Mainstem reaches with Chinook and coho, but no chum, were given a rating of 2 (moderately abundant, >200 and <400). Reaches with only coho were given a rating of 3 (not abundant, >25 and <200). Reaches with only steelhead and/or cutthroat trout were given a rating of 4 (very few or none, <25), since these fish can spawn more than once (iteroparous). Tidal reaches below areas of chum spawning were given a rating of 1 (very abundant, >400 and <800); it was assumed carcasses from spawning reaches above are washed into these reaches.

An estimate of the current number of salmon carcasses per mile was derived from natural spawn escapement estimates, weir/trap counts, EDT reach length data, and SSHIAP fish distribution data. SSHIAP categorizes fish distribution into known, presumed, and potential habitat by species, and EDT reaches were delineated using these categories during development of the EDT template. Using potential fish distribution, EDT reach lengths were summed to develop the total number of miles of habitat available for each species. Where available, the natural spawn escapement estimate was divided by the corresponding number of miles of habitat to generate the average number of carcasses per mile for each species. These values were summed according to the species present within each reach to develop an estimate of the total number of carcasses per mile within the reach. Calculations were completed for chum, Chinook and coho only, as steelhead and cutthroat trout are iteroparous and likely contribute few carcasses. When escapement data was not available, expert opinion was used to estimate carcass abundance.

The Kalama River currently supports naturally produced populations of fall Chinook, coho, winter & summer steelhead, cutthroat trout and possibly spring Chinook. Chum may exist in low numbers, but fall stream surveys, weir counts at the WDFW Modrow Road Weir, and trap counts at the WDFW Kalama Falls and Fallert Creek hatcheries recover/trap few (if any) chum, annually. WDFW hatcheries release early/late coho, fall/spring Chinook, and summer/winter steelhead into the watershed.

Currently, a jump curtain installed across Lower Kalama Falls (located at the top of Kalama 5) prevents most returning adult salmonids from jumping the falls. Fish accessing the upper watershed are forced to use a fish ladder/trap, where they can be identified and enumerated before being passed upstream (pers. com. Wagemann, WDFW). WDFW current management strategy allows all naturally produced winter/summer steelhead, and cutthroat to be passed upstream. In addition, a pre-determined number of wild broodstock summer/winter steelhead and spring Chinook are passed upstream for research purposes. Steelhead and cutthroat trout are iteroparous and provide few carcasses. Based on spring Chinook densities, all mainstem and tributary reaches above Lower Kalama Falls (Kalama 6 upstream) were given an EDT rating of 4. Nutrient enhancement through carcass placement does occur above Lower Kalama Falls, but was not included in developing EDT ratings.

Escapement estimates are available for fall Chinook below Lower Kalama Falls, and a ten year average (1992-2001) of 3,674 was used for developing carcass estimates. Estimates of coho abundance are not available for the Kalama River. During EDT analysis of the Elochoman River, it was estimated 6800 coho return on average from WDFW Elochoman Hatchery production, which releases fewer coho than WDFW Kalama River hatcheries. This estimate was used as a surrogate for the Kalama River, assuming it was likely biased low. EDT reaches Kalama 1-5 were given an EDT rating of 0, and tributaries below Lower Kalama Falls were given a rating of 3.

*Level of Proof*— A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the historic and current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. This rating was used as a baseline for benthos diversity and was assigned to all reaches for historic conditions.

Current Wind River data indicates EDT scores in disturbed Rosgen B-channels are similar to historic scores of 0.6 and in disturbed C-channels scores are reduced to 1.3. EDT ratings in Kalama 2 and Fallert (Hatchery) Creek were reduced to 1.3. Kalama 1-tidal is currently, and likely was historically, an area of sediment deposition, and macroinvertebrate complexity is likely reduced. This reach was given a rating of 1.0 and 2.0 for the historic and current conditions, respectively. All other reaches were given a rating of 0.6

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Acknowledgements

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Weyerhaeuser for access to these streams for spawning ground surveys and to collect habitat data used in this modeling effort. We thank the staff at Mobrand Biometrics for running the model especially Kevin Malone and Jennifer Garrow.

| | **Appendix B: EDT reaches and descriptions** |
|---|---|
| **EDT Reach** | **EDT Reach Description** |
| Arnold Cr | Description: Arnold Creek (1.9 miles known, 1.9 miles presumed steelhead dist. = 3.8 miles); Confinement: confined; Fish Species present: WS, SS |
| Bear Cr | Description: Bear Creek (1.8 miles known, 0.3 potential steelhead dist. = 2.1 miles; Confinement: confined; Fish Species present: WS, SS |
| Bush Cr | Description: Bush Creek (0.9 miles of presumed steelhead dist.); Confinement: unconfined to moderate; Fish Species present: WS, SS |
| Cedar Cr | Description: Cedar Creek (0.8 miles known steelhead dist.); Confinement: moderate to confined; Fish Species present: WS |
| Dee Cr | Description: Dee Creek (0.8 miles known steelhead dist.); Confinement: confined; Fish Species present: WS, SS |
| Elk Cr | Description: Elk Creek (0.4 miles of known steelhead distribution; Confinement: confined; Fish Species present: WS, SS |
| Gobar Cr | Description: Gobar Creek (6.0 miles known, 4.1 miles presumed steelhead dist. = 10.1 miles); Confinement: confined to moderate; Fish Species present: WS, SS |
| Hatchery Cr | Description: Hatchery Creek (0.2 miles known steelhead, 2.7 presumed = 2.9 miles); Confinement: confined; Fish Species present: WS |
| Indian Cr | Description: Indian Creek (0.2 miles known steelhead dist.); Confinement: confined; Fish Species present: WS |
| Jacks Cr | Description: Jacks Creek (1.7 miles known steelhead dist.); Confinement: confined; Fish Species present: WS, SS |
| Kalama 1 tidal | Description: mouth to Spencer Creek; Confinement: unconfined; Fish Species present: SC, FC, WS, SS, CH |
| Kalama 10 | Description: Wildhorse Creek to Gobar Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 11 | Description: Gobar Creek to Arnold Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 12 | Description: Arnold Creek to unnamed Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 13 | Description: unnamed Creek to Jacks Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 14 | Description: Jacks Creek to Lost Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 15 | Description: Lost Creek to Elk Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 16 | Description: Elk Creek to Bush Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 17 | Description: Bush Creek to Wolf Creek; Confinement: confined to moderate; Fish Species present: SC, WS, SS |
| Kalama 18 | Description: Wolf Creek to Langdon Creek; Confinement: moderate confinement; Fish Species present: SC, WS, SS |
| Kalama 19 | Description: Langdon Creek to North Fork Kalama River; Confinement: moderate confinement; Fish Species present: SC, WS, SS |
| Kalama 2 | Description: Spencer Creek to Cedar Creek; Confinement: confined; Fish Species present: SC, FC, WS, SS, CH |
| Kalama 20 | Description: North Fork Kalama River to Lakeview Peak Creek; Confinement: moderate confinement; Fish Species present: SC, WS, SS |
| Kalama 21 | Description: Lakeview Peak Creek to Upper Kalama Falls; Confinement: moderate confinement; Fish Species present: SC, WS, SS |
| Kalama 3 | Description: Cedar Creek to Hatchery Creek; Confinement: moderate confinement; Fish Species present: SC, FC, WS, SS, CH |
| Kalama 4 | Description: Hatchery Creek to Indian Creek; Confinement: moderate to confined; Fish Species present: SC, FC, WS, SS, CH |
| Kalama 5 | Description: Indian Creek to lower Kalama Falls; Confinement: confined; Fish Species present: SC, FC, WS, SS, CH |
| Kalama 6 | Description: lower Kalama Falls to Little Kalama River; Confinement: confined to moderate; Fish Species present: SC, WS, SS |
| Kalama 7 | Description: Little Kalama River to Summers Creek; Confinement: confined; Fish Species present: SC, WS, SS |
| Kalama 8 | Description: Summers Creek to Knowlton Creek; Confinement: moderate confinement; Fish Species present: SC, WS, SS |
| Kalama 9 | Description: Knowlton Creek to Wildhorse Creek; Confinement: moderate to confined; Fish Species present: SC, WS, SS |
| Knowlton Cr | Description: Knowlton Creek (0.3 miles known steelhead dist.); Confinement: confined; Fish Species present: WS, SS |

| | **Appendix B: EDT reaches and descriptions** |
|---|---|
| **EDT Reach** | **EDT Reach Description** |
| Lakeview Peak Cr | Description: Lakeview Peak Creek (3.4 miles known steelhead dist.); Confinement: moderate to confined; Fish Species present: WS, SS |
| Langdon Cr | Description: Langdon Creek (1.6 miles known steelhead distribution); Confinement: unconfined to moderate to confined; Fish Species present: WS, SS |
| Little Kalama R | Description: mouth to Dee Creek (3.2 miles known steelhead dist.); Confinement: confined; Fish Species present: WS, SS |
| Lost Cr | Description: Lost Creek (0.7 miles of presumed steelhead dist.); Confinement: confined; Fish Species present: WS, SS |
| NF Kalama | Description: North Fork Kalama (3.1 miles known, 5.6 miles presumed steelhead dist - total 8.7 miles); Confinement: unconfined to moderate to confined; Fish Species present: WS, SS |
| Spencer Cr | Description: Spencer Creek (1.3 miles known steelhead dist.); Confinement: confined to moderate to unconfined; Fish Species present: WS |
| Summers Cr | Description: Summers Creek (0.1 miles known steelhead dist.); Confinement: confined; Fish Species present: WS, SS |
| Unnamed Cr (27.0087) | Description: Unnamed Creek (1.3 miles presumed steelhead dist.); Confinement: confined??; Fish Species present: WS, SS |
| Wildhorse Cr | Description: Wildhorse Creek (2.4 miles known, 1.8 miles presumed, 0.6 miles potential steelhead dist. = 4.8 miles); Confinement: confined; Fish Species present: WS, SS |
| Wolf Cr | Description: Wolf Creek (1 mile of known steelhead distribution); Confinement: moderate to confined; Fish Species present: WS, SS |

# E.4. Toutle River

## E.4.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treatment Model (EDT) for the Toutle River. In this project we rated over 110 reaches with 46 environmental attributes per reach for current conditions and another 46 for historical conditions. Over 5,000 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact, less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data for most reaches. However, data is available from Gobar Creek (a Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.4.2. Recommendations

1. Adult chum salmon, Chinook salmon, and steelhead population estimates should continue for the basin. However, more emphasis should be placed on determining the number of hatchery and wild spawners and the reproductive success of hatchery spawners. Winter steelhead counts on the North Fork Toutle are based on rack counts at the Toutle Collection Facility (TCF) and are considered accurate and precise. Winter steelhead estimates are made for the South Fork Toutle based upon redd count expansion, while fall Chinook estimates are made for the South Fork Toutle and Green River based upon index counts and peak count expansion. These estimates are based on an assumed observer efficiency and are likely to be less reliable. Winter steelhead counts on the Green River are index counts only, while chum and coho salmon counts in the Toutle Basin are periodic and not population estimates. Funding should be secured to develop accurate and precise adult estimates for chum, Chinook and coho salmon and winter steelhead. Smolt populations are currently not monitored in the basin. Funding should be secured to generate smolt population estimates for the above species as well. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective.
2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating, as would field surveys.

3. Empirical sediment data was not available for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.
4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Flow monitoring in the mainstem, South Fork and North Fork Toutle, and Green Rivers is conducted in several locations. Flow monitoring should be continued. Bed scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. USFS and USGS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey only a few "representative" mainstem and tributary reaches. In addition, glides and pools were distinguished subjectively and not quantitatively. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves 1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. A combination of Ecology and OSU estimates of Benthic Index of Biological Integrity (B-IBI) collected in the Wind and Cowlitz River basins were used to develop EDT ratings. These estimates should be completed in this and other SW Washington watersheds.
8. Obstructions were not rated and passage was assumed to be 100%. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. These ratings should be updated using SSHIAP database.

## E.4.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This watershed originates from Mount St. Helens. The maximum elevation is approximately 8,300 feet on the summit of Mount St. Helens (USFS, 1997). The anadromous zone extends beyond Miner's Creek on the Green River (~1986 feet elevation), Castle and Coldwater Creeks on the North Fork Toutle (~2200 feet elevation), and Disappointment Creek on the South Fork Toutle (~2200 feet elevation). The Upper Toutle River Watershed Analysis (USFS 1997) indicates 70% of the upper basin is in the transient snow zone and subject to snow-melt and rain-on-snow events. These events influence lower mainstem reaches, but effects are likely masked by tributary flow inputs as one progresses downstream. The Integrated Watershed Assessment (IWA) completed for the Lower Columbia Fish Recovery Board (LCFRB) examined the current condition of key watershed processes by Hydrologic Unit Code (HUC) (LCFRB 2003). IWA results present the percent rain-on-snow area by HUC. EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries (LCFRB 2003). Rain-on-snow percentages range from 0 to 84% for HUCS with associated EDT reaches (Table E7-27). As a general rule, reaches with percentages >45% were given an EDT rating of two (rain-on-snow transitional), and reaches with <45% were given an EDT rating of three (rainfall dominated). Exceptions to this are as follows: the percentage of rain-on-snow area for the upper portions of the Green, North Fork (NF) Toutle and South Fork (SF) Toutle watersheds decreases due to these areas being snowmelt zones. To determine the split between rainfall dominated and rain-on-snow zones, the percentage of rain-on-snow area was examined starting at the mouth of the Green, NF and SF Toutle Rivers and working upstream until the percentage reached >=45%. Mainstem and tributary reaches upstream of this point were rated as rain-on-snow transitional areas.

**Table E7-27. % Rain-on-snow area for HUCs with associated EDT reaches.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC % Rain on Snow Area |
|---|---|---|
| 17080005030101 | Coldwater Cr | 25 |
| 17080005030201 | NF Toutle 13(.2) | 43 |
| 17080005030202 | NF Toutle 13(.3) | 46 |
| 17080005030205 | Castle Cr | 33 |
| 17080005030301 | Hoffstadt Cr 1(.75) | 60 |
| 17080005030302 | Hoffstadt Cr 1(.25), Hoffstadt Cr 2 | 59 |
| 17080005030303 | Alder Cr | 61 |
| 17080005030304 | NF Toutle 7, 8, 9, 10, 11, RB 8 | 24 |
| 17080005030305 | Bear Cr (NF Trib) | 45 |
| 17080005030306 | NF Toutle 12, 13(.5), Deer Cr | 45 |
| 17080005040201 | Green River 7, 8, 9, Tradedollar | 49 |
| 17080005040202 | Miners Cr | 15 |
| 17080005040203 | Shultz Cr 1, 2, Shultz Cr trib | 39 |
| 17080005040301 | Green River 6, Cascade Cr | 84 |
| 17080005040302 | Elk Cr 1, 2, Elk Cr trib | 84 |
| 17080005040401 | Green River 5(.5) | 73 |
| 17080005040402 | Green River 1, 2, 3, Beaver Cr, Jim Cr | 6 |
| 17080005040403 | Green River 4, Devil's Cr | 38 |
| 17080005040404 | Green River 5(.5) | 24 |
| 17080005050101 | SF Toutle 20, Disappointment Cr | 19 |
| 17080005050201 | SF Toutle 16, 17, 18, 19, RB 3, RB 4 | 30 |
| 17080005050202 | LB8, Trouble Cr | 33 |
| 17080005050301 | SF Toutle 11, 12, 13, Bear Cr(.5), Harrington Cr | 46 |
| 17080005050302 | SF Toutle 14, 15, LB 7, RB 2, Bear Cr(.5) | 47 |
| 17080005050401 | SF Toutle 4, 5, Brownell Cr 1, 2, Jordan, Thirteen, Eighteen | 22 |
| 17080005050402 | RB 10, Studebaker Cr 1, 2 | 0 |
| 17080005050403 | SF Toutle 2, 3, Johnson Cr | 18 |
| 17080005050404 | SF Toutle 6, 7, 8, LB 5, Twenty Cr, Big Wolf Cr | 34 |
| 17080005050405 | SF Toutle 9, 10, LB 6, Whitten Cr | 53 |
| 17080005070603 | Toutle 6, 7, 8, LB 4, RB 1 | 0 |
| 17080005070604 | Toutle 3, 4, 5, LB 2, LB 3, Stankey Cr, Rock Cr, Hollywood Gorge | 0 |
| 17080005070607 | Toutle 1, 2, LB 1 | 0 |
| 17080005070301 | NF Toutle 1, 2, 3, 4, 5, 6, RB 5, RB 6, RB 7, LB 9 | 0 |
| 17080005070302 | SF Toutle 1, LB 10, Wyant Cr 1, 2 | 22 |
| 17080005070401 | Toutle 9, Hemlock Cr 1, 2, RB 9, Silver Lake 1, Unnamed Lake trib | 0 |
| 17080005070402 | Silver Lake 2, Sucker Cr | 0 |
| 17080005070403 | Hemlock Cr 3 | 3 |

To verify these ratings and determine the extent of downstream influence from rain-on-snow reaches, mean monthly flow data (USGS 2004) was plotted for nine Toutle River gauge locations and compared to EDT flow patterns for groundwater influenced, rainfall dominated, rain-on-snow transitional, spring snowmelt, and glacial runoff systems. EDT ratings for reaches with gauge data were assigned based on the dominant flow regime at each gauge (Table E7-28). Results from USGS gauge data support the ratings assigned by using HUC percent rain-on-snow values.

Natural flow regime ratings were assumed to be the same for both historical and current conditions. Each reaches natural flow regime was used to assign shape patterns when rating other EDT attributes.

**Table E7-28**. **EDT flow patterns assigned to flow regimes at USGS gauges.**

| USGS Gauge Location | Flow Regime | EDT Pattern Assigned |
|---|---|---|
| Green R. above Beaver Ck (EDT = Green 3) | February peak with higher (but variable) flows into June before steady decrease through summer. | Rain-on Snow Transitional |
| Green R. near Toutle (EDT=Green 2 (lower)) | February peak with higher (but variable) flows into May before steady decrease through summer. | Rain-on Snow Transitional |
| NF Toutle at St. Helens (EDT = NF Toutle 11) | March peak with variable high flows through June before steady decrease into summer. Only 4 years of data from the late 1930s. Evidence of snowmelt effects. | Rain-on Snow Transitional |
| NF Toutle below SRS (EDT = NF Toutle 7 (upper)) | February peak with variable high flows through May before steady decrease into summer. | Rain-on Snow Transitional |
| NF Toutle at Kid Valley (EDT = NF Toutle 3 | February peak with general decline through Spring. Flow spikes in late Spring that may be due to rain-on-snow. Primarily rainfall dominated. | Rainfall dominated |
| SF Toutle at Camp 12 (EDT = SF Toutle 2 (upper)) | February peaks with general decline through Spring. Flow spikes in late Spring that may be due to rain-on-snow. Primarily rainfall dominated. | Rainfall dominated |
| SF Toutle at Toutle (EDT = SF Toutle 2 (lower)) | February peak with steady decrease through spring into summer. | Rainfall dominated |
| Toutle near Silver Lake (EDT = Toutle 8) | January peak with steady decrease through spring into summer. | Rainfall dominated |
| Toutle at Tower Road (EDT = Toutle 3) | January/February peak with steady decrease through spring into summer. | Rainfall dominated |

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

## Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watershed does not have artificial flow regulation, and was given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Direct measures of interannual high flow variation are not available for most basins. USFS has conducted watershed analyses in the EF Lewis, NF Lewis, Wind, White Salmon, Washougal, Kalama, Cowlitz, and Cispus Rivers and Rock Creek (USFS 1995a, USFS 1995b, USFS 1996a, USFS 1996b, USFS 2000). Peak flow analysis was conducted using the State of Washington "standard methodology for conducting watershed analysis". Primary data used for the peak flow analysis pertains to vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-29.

**Table E7-29**. **Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10 -12% |
| Rock Cr | | 1 - 5% |
| Upper Kalama | | 5 - >10% |
| Cispus | | <10% |

For watersheds in which the two-year peak flow (Q2yr) increases 10% the EDT rating is 2.25. For increases of 20% the EDT rating is 2.5. The USFS Upper Toutle River Watershed Analysis (1997) found peak flow increases of >10% in 5 of 9 sub-basins. A Q2yr analysis (using EDT manual protocol) of USGS flow data for the Toutle was inconclusive due to a change in gauge location during the time series. If the effects of moving the gauge are assumed to be negligible, results indicate a peak flow increase ranging from 7 - 31%. Q2yr analyses on the Kalama, Naselle and Wind Rivers showed peak flow increases ranging from 10 to 17%, or an EDT rating of ~2.3 to 2.4. For the Toutle watershed, a 2.3 rating was assumed to be representative of tributaries and forested areas not affected by the eruption of Mount St. Helens (Green River and Silver Lake watersheds). The NF and SF Toutle likely have increased peak flows from eruption damage and the subsequent salvage logging that took place. The NF Toutle (above the Green) and SF Toutle were rated at 2.5 and 2.4, respectively. The mainstem Toutle was rated using an average of the Green, NF Toutle and SF Toutle ratings; a value of 2.4. The NF Toutle below the mouth of the Green River was also given a rating of 2.4; an average of ratings for the Green River and NF Toutle above the mouth of the Green. Coldwater and Castle Creeks originate from Coldwater and Castle Lakes, respectively. These lakes were created by debris flows from the Mount St. Helens eruption. Peak flows in these tributaries are likely buffered by the lakes and were given an EDT rating of 2.0.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute's rating for watersheds in pristine condition. Research on the effects of land use practices on summer low flow is inconclusive. Therefore, template and current conditions were rated the same (EDT rating of 2), except where noted.

The LCFRB Level 1 assessment for WRIA 25 & 26 (2001) presents average water usage in 2000 (surface water) for the Toutle River at 0.11 million gallons/day, which translates to approximately 0.1 cubic feet /second (cfs). Total water rights for the Toutle Watershed are listed as an instantaneous quantity of 6596 gpm (14.6cfs). Exhibit 4-1 presents a figure of surface water rights distribution, which is clustered in the lower reaches of the Toutle Basin from Kid Valley on the NF Toutle and Studebaker Creek/Silver Lake on the SF Toutle to the mouth. Average low flow (August) for the Toutle River is 484cfs at the USGS Tower Road Gauge (USGS 2004). Water withdrawals were considered minimal and likely do not affect summer low flows.

Historically, Silver Lake was naturally dammed by a mudflow from Mount St. Helens, and lake level was reportedly maintained by a series of beaver dams. Flow was highly variable and floods were common occurrences. An earthen and concrete dam was built in the early 1970's for flood and lake level control, which stabilized flows from the lake (Caromile and Jackson, 2000). Weyerhaeuser surveyed the Silver Lake watershed in 1994. They found that Outlet Creek (EDT reaches Hemlock 1&2) had the most serious low flow problems with low to non-existent summer flows limiting available pool habitat (Wade 2000). Silver Lake dam regulates flows and keeps lake levels high in summer by reducing flows to Outlet Creek. EDT reaches Silver Lake 1 & 2 were given a rating of 1.5, while Hemlock 1 & 2 (Outlet Creek) were given a rating of 2.5.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of derived information and expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Flow – Intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. This attribute was given an EDT rating of 0 for current conditions due to the lack of storm water runoff and hydroelectric development in the watershed. There are no major metropolitan areas in this watershed with large areas of impervious surfaces.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – Intra-annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in this watershed. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in interannual variability in high flows (pers. com. Lestelle, Mobrand Biometrics, Inc). Ratings for interannual variability in high flow were translated directly into ratings for intra-annual flow.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. Stream length was assumed to be the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*— Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in Lower Columbia River tributaries were surveyed by Steven VanderPloeg (WDFW) in 2003. Wetted widths corresponding to average summer low flows (August) and winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. The percent increase between low and high flow widths for all subbasins was compared to the EDT confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data (EDT reach Kalama 14). A possible explanation for this relationship is that all unconfined reaches in the dataset have been down-cut due to lack of large woody debris and hydroconfinement. Based on this data, general "rules" were developed relating wetted width minimum and maximum values. A 1.6 multiplier (60%) was assumed to be appropriate for expanding wetted width minimum values in mainstem reaches with moderate confinement and for all tributary reaches. In unconfined mainstem reaches, where down-cutting has not occurred, it was assumed minimum widths would (on average) double under average high flow conditions, and a 2.0 (100%) multiplier was used for these reaches. Conversely, in heavily confined mainstem areas (i.e. canyons) it was assumed minimum widths can not increase much as flow increases and a 1.3 (30%) multiplier was used in these reaches.

For the Toutle Basin, VanderPloeg (2003) was only able to conduct habitat surveys during times of high flow. Additional width data was collected during surveys conducted in October and November of 2000 for use by SSHIAP (pers. com. VanderPloeg and Grobelny, WDFW). These sources were used to develop wetted width maximum values (see "Channel Width – month maximum width" section). Wetted width minimum values were calculated using the general rules described above. Wetted width maximum values for each reach were multiplied by the inverse of the appropriate multiplier determined by the confinement of the reach.

Exceptions/variations to these rules are as follows. Minimum widths for non-surveyed reaches of the SF Toutle were developed from surveyed maximum widths in SF 2, 3 and 13. SF 2 is unconfined, SF 3 is moderately confined, but the survey was conducted in a confined area of the reach, and SF 13 is moderately confined, but post eruption channel widths have increased also increasing sinuosity. Wetted width minimums were calculated by multiplying wetted width maximums by 1/2 for SF 2 and SF 13 and by 1/1.3 for SF 3. Minimum widths for SF 2 and 3 were averaged and applied to SF 1-11 and the minimum for SF 13 was applied to SF 12-15. The SF 13 minimum width value was reduced by 5 feet in SF16 (for SF 16-19) and again in SF 20 to account for flow inputs by Trouble and Disappointment Creeks, respectively. Minimum widths for non-surveyed reaches of the NF Toutle were developed from surveyed maximum widths in NF 6&7 by multiplying by 1/1.6. Minimum values from NF 6 were applied to NF 1-5 and minimums from NF 7 were applied to NF 8-13.

*Level of Proof*— A combination of empirical observations, expansion of empirical observations, derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Representative reaches in Lower Columbia River tributaries were surveyed by Steve VanderPloeg (WDFW) in 2003. Wetted widths corresponding to average summer low flows (August) and winter high flows (January) were measured as part of these surveys, however, for the Toutle Basin only high flow surveys were conducted (VanderPloeg 2003). Additional surveys were conducted during October and November of 2000 to collect spot measurements of wetted and bankfull width for use by SSHIAP (pers. com. VanderPloeg and Grobelny, WDFW). Using USGS gauge data (2004) for the SF Toutle, stream flows corresponding to survey dates from both these data sources were compared to mean January flows (for all available years). Stream flows during the 2000 and 2003 surveys averaged 37% and 77% of mean January flows, respectively. Wetted widths measured during these surveys are likely less than the true maximum wetted width during average January flows, more so for the 2000 than the 2003 surveys. Due to the lack of other reach specific width data, these values were used with the knowledge that they are likely biased low. Survey locations were linked with the appropriate EDT reach and wetted width measurements were assumed to be representative of the entire reach. Table E7-30 lists the EDT reaches where surveys were conducted.

**Table E7-30. Toutle River EDT reaches surveyed and type of survey conducted.**

| EDT Reach | Habitat Survey Conducted |
|---|---|
| Bear Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| Cascade Creek | Representative reaches - VanderPloeg 2003 |
| Devils Creek | Representative reaches - VanderPloeg 2003 |
| Eighteen Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| Elk Creek 1 | Representative reaches - VanderPloeg 2003 |
| Green River 1 | Representative reaches - VanderPloeg 2003 |
| Green River 5 | Representative reaches - VanderPloeg 2003 |
| Green River 8 | Representative reaches - VanderPloeg 2003 |
| Harrington Creek | Representative reaches - VanderPloeg 2003 |
| Jim Creek | Representative reaches - VanderPloeg 2003 |
| Johnson Creek | Representative reaches - VanderPloeg 2003 |
| Johnson Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| LB trib5 (not listed) | Spot measurements - VanderPloeg & Grobelny 2000 |
| LB trib6 (not listed) | Spot measurements - VanderPloeg & Grobelny 2000 |
| NF Toutle 6 | Representative reaches - VanderPloeg 2003 |
| NF Toutle 7 | Representative reaches - VanderPloeg 2003 |
| SF Toutle 13 | Representative reaches - VanderPloeg 2003 |
| SF Toutle 2 | Spot measurements - VanderPloeg & Grobelny 2000 |
| SF Toutle 3 | Representative reaches - VanderPloeg 2003 |
| Studebaker Cr 1 | Spot measurements - VanderPloeg & Grobelny 2000 |
| Thirteen Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| Toutle 1 | Representative reaches - VanderPloeg 2003 |
| Toutle 3 | Representative reaches - VanderPloeg 2003 |
| Toutle 9 | Representative reaches - VanderPloeg 2003 |
| Trouble Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| Twenty Creek | Spot measurements - VanderPloeg & Grobelny 2000 |
| Whitten Creek | Spot measurements - VanderPloeg & Grobelny 2000 |

For non-surveyed reaches, wetted width maximum values were calculated and/or extrapolated from surveyed reach values. Utilizing Lower Columbia River tributary width data from VanderPloeg's 2003 surveys, the percent increase between low and high flow widths for all subbasins was compared to the EDT confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data (EDT reach Kalama 14). A possible explanation for this relationship is that all unconfined reaches in the dataset have been down-cut due to lack of large woody debris and hydroconfinement. Using only Kalama mainstem reach data (EDT reaches Kalama 2, 5, 11, 17) the mean increase in stream width is 30%. A possible explanation for this is that most of the Lower Kalama watershed is currently confined and/or hydroconfined. Based on this data, general "rules" were developed relating wetted width minimum and maximum values. A 1.6 multiplier (60%) was assumed to be appropriate for expanding wetted width minimum values in reaches with moderate confinement and in all tributary reaches. In unconfined mainstem reaches, where down-cutting has not occurred, it was assumed minimum widths would (on average) double under average high flow conditions, and a 2.0 (100%) multiplier was used for these reaches. Conversely, in heavily confined mainstem areas (i.e. canyons) it was assumed minimum widths can not increase much as flow increases and a 1.3 (30%) multiplier was used in these reaches.

These general rules were used to develop wetted width values for the mainstem Toutle, NF Toutle, and SF Toutle as follows. Widths for non-surveyed reaches of the SF Toutle were developed from surveyed maximum widths in SF 2, 3 and 13 by first developing wetted width minimums. SF 2 is unconfined, SF 3 is moderately confined, but the survey was conducted in a confined area of the reach, and SF 13 is moderately confined, but post eruption channel widths have increased also increasing sinuosity. Wetted width minimums were calculated by multiplying maximum widths by 1/2 for SF 2 and SF 13 and by 1/1.3 for SF 3. Width minimums from SF 2 and SF 3 were averaged and applied to SF 1-11 and minimums from SF 13 were applied to SF 12-15. The SF 13 minimum width value was reduced by 5 feet in SF16 (for SF 16-19) and again in SF 20 to account for flow inputs by Trouble and Disappointment Creeks, respectively. Wetted Width maximums were then back-calculated for non-surveyed reaches using the multiplier appropriate to each reaches confinement. Widths for non-surveyed reaches of the NF Toutle were developed from surveyed maximum widths in NF 6&7 by first developing wetted width minimums. Minimum widths were calculated by multiplying maximum widths by 1/1.6. Minimum widths from NF 6 were applied to NF 1-5 and minimums from NF 7 were applied to NF 8-13. Wetted width maximums were then back-calculated for non-surveyed reaches using the multiplier appropriate to each reaches confinement. Wetted width maximums for non-surveyed mainstem Toutle reaches 2,4,6,7,&8 were assigned the average value of surveyed reaches Toutle 1,3 and 9. The reciprocal of the 2 multiplier (1/2) was used to calculate wetted width minimums for these reaches and Toutle 5 & Hollywood Gorge. Wetted width maximums for Toutle 5 were back-calculated from the minimum value using a 1.6 multiplier and for Hollywood Gorge by using a 1.3 multiplier.

For the Green River mainstem and Elk Creek, wetted width maximum values were assigned to non-surveyed reaches using the "split rule", which is defined as follows. For reaches above a split (confluence of 2 tributaries), wetted width was calculated by: {(1.5*downstream reach width)*0.5} for even splits. For uneven splits, the multiplier was adjusted to compensate. In a 60:40 split: (1.5*drw)*0.6 and (1.5*drw)*0.4; and for a 70:30 split: (1.25*drw)*0.7 and (1.25*drw)*0.3. Wetted width data was available for surveyed reaches Green 1,5,8 and Elk Creek 1. Wetted width values produced by the 70:30 "split rule" were found to best fit the width data from surveys and this rule was used to increase or decrease widths working upstream and downstream between surveyed reaches.

For non-surveyed tributary reaches (other than Elk Creek), width data from surveyed tributary reaches was used to develop representative width values for small and medium sized tributaries. Small tributaries were defined as those with a maximum wetted width <20 feet, while medium tributaries were defined as being >=20feet. Maximum wetted width values from surveyed reaches were averaged for each tributary category to develop representative values of 13.5 and 27.6 feet for small and medium sized tributaries, respectively. Non-surveyed tributary reaches were assigned to the small or medium tributary category based upon review of ortho-photos via GIS to determine drainage size and from professional knowledge of the area.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, expansion of empirical observations, derived information and expert opinion were used to develop ratings and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as % gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—By definition, template and current values for this attribute are the same. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003. Confinement ratings were estimated during these surveys (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps (1:24,000) and ortho-photos were consulted (via GIS) to verify and/or adjust ratings. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4 (Table E7-31). There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings.

**Table E7-31. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures and activity) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. Most hydro-modification consists of roads in the floodplain and diking. The SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, USGS topography maps (1:24,000 via GIS), and WRIA 26 LFA (Wade 2000) were reviewed and professional judgment was used to assign EDT ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, it was assumed that for historical conditions the percentage of pools was significantly higher than for current conditions. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, pool habitat was estimated to be 40% and 30% respectively (WFPB 1994).

Tailouts were assumed to represent 15-20% of pool habitat, which is the current range from WDFW surveys (VanderPloeg 2003). Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data (VanderPloeg 2003) indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

Data for current habitat types in the Toutle Basin is lacking. The following adjustments were made to historic habitat ratings: the percentages of pool, tail-out, and small cobble riffle habitat were reduced to 80% of the historical ratings. In reaches where historic beaver pond habitat was present, current ratings were reduced to 1% or less. In reaches with historic backwater pool habitat, current ratings were reduced to 1%. The sum of the differences from these adjustments was added to percent glides, insuring the sum of all habitat types equaled 100%.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A, B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. Most of the Toutle basin is moderately confined to confined. An EDT rating of 0% was assigned to moderately confined/confined reaches. Of the unconfined mainstem reaches on the NF, SF, mainstem Toutle and Green Rivers only reaches NF Toutle 1&2, SF Toutle 1&2 and Toutle 1&9 have significant potential for meandering and off-channel habitat formation. Historically, Toutle 1 was given a rating of 20% and NF Toutle 1&2, SF Toutle 1&2 and Toutle 9 were rated at 10%. In the current condition, ratings were reduced to 5% for all of these reaches. Hydroconfinement in Toutle 1 from Interstate-5 has likely caused the greatest reduction in off-channel habitat within the basin.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— Currently only two barrier reaches are identified in the Toutle Basin EDT model – the Sediment Retention Structure (SRS) and the Toutle Collection Facility (TCF) referred to as the "fishtrap". Historically, these structures did not exist. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for these barriers. Most tributaries are represented in the EDT model by a single reach. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon are more impacted by barriers, due to their preference for spawning in small tributaries. As barrier inventories become more complete and available for the Toutle Basin it would be valuable to incorporate these into the EDT model.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

The LCFRB Level 1 assessment for WRIA 25 & 26 (2001) Exhibit 4-1 presents a figure of surface water rights distribution. Most surface water rights in the Toutle Watershed are for small-scale domestic and agricultural usage, and are clustered along the mainstem Toutle, Silver Lake, lower Studebaker and Wyant creeks, and the NF Toutle up to Kid Valley. The Level 1 assessment (2001) Table 7.31 lists total consumptive water rights at 6,596 gallons per minute (gpm) (instantaneous usage) which is equivalent to ~14.6 cubic feet/second (cfs). Actual usage in 2000 (Table 3-10B) was estimated at 0.11 million gallons/day or ~0.1 cfs. Average August flow for the Toutle from the USGS Gauge at Tower Road (USGS 2004) is 484 cfs. Most residents in the watershed are on domestic well water. However, the Toutle Regional Community Water System is supplied water pumped from the Cowlitz river, which is returned to the Toutle River via a solid waste treatment facility near the town of Toutle (pers. com. Cowlitz County Public Works Department). Legal water withdrawals for these areas were considered to be minimal and the corresponding EDT reaches were rated at 0.1.

EDT reaches (including tributaries) above the North Toutle Hatchery on the Green River (Green 2 upstream), above NF Toutle 6, and all of the SF Toutle (except for Studebaker 1) are primarily forested areas managed for timber harvest. Stream adjacent homes in these areas are rare or non-existent. Withdrawals above these areas were assumed to be minimal or non-existent and corresponding EDT reaches were given a rating of 0. Other tributary reaches in the lower watershed without stream adjacent homes, etc. were also rated at 0.

The intake for the North Toutle Hatchery is the divider between EDT reaches Green 1&2. This intake provides water to maintain the facility year round. The intake is screened and water is released back into the Green River at the lower end of the facility.  EDT reach Green 1 was rated at a 2.  The water intake for the acclimation pond on Brownell Creek is in EDT reach Brownell 1.  The intake is screened and water is returned into Brownell creek at the lower end of the pond. This reach was given a rating of 1.  The intake for the Toutle Collection Facility fish trap is in EDT reach NF Toutle 7.  The intake is utilized approximately 1-2 days per week to “water-up” the trap for fish collection.  This reach was given a rating of 0.5.

*Level of Proof*—A combination of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.  For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins.  Historic bed scour was rated using the look-up table developed by Dan Rawding (WDFW).  This table was modified to incorporate the new EDT revisions for bed scour ratings.  The table is based on professional judgment.  It relates bed scour to confinement, wetted width (high flow), and gradient and assumes scour increases as gradient and confinement increase.

Historic EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as follows:  it was assumed increases in peak flow and hydroconfinement also increased bed scour, and scour ratings were increased 0.049 for each tenth (0.1) of increase in the EDT peak flow rating and for each point (1.0) increase in the hydroconfinement rating.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—Reaches of the Lower Toutle Watershed are rainfall dominated.  In general, EDT mainstem and tributary reaches on the Green River, above SF Toutle 6, and above NF Toutle 7 were rated as rain-on-snow transitional.  Anchor ice and major icing events are rare or non-existent.  EDT ratings of 0 were assigned to all reaches in the historical and current condition.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

For current conditions, riparian zones with mature conifers are rated at 1.0. Riparian zones with saplings and primarily deciduous trees are rated at 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees are rated at 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydroconfinement should be rated as a 1 to 1.5. When vegetation is lacking and/or hydroconfinement/residential development exists, riparian ratings were increased based upon the severity of each.

Information was compiled from: the WA State Conservation Commission LFA for WRIA 26 (Wade 2000), EDT Habitat Surveys by VanderPloeg (2002) and VanderPloeg & Grobelny (pers. com. WDFW), the SSHIAP and DNR GIS roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000 via GIS). The eruption of Mount St. Helens decimated much of the Toutle watershed - mudflows scoured and widened stream channels and destroyed riparian cover. Salvage logging removed much of the timber left after the blast. Currently, the watershed is in a state of recovery with vast tracts of immature trees, and many areas of deciduous growth. Sediment deposition from the eruption has created large reaches with braided, meandering channels, and unstable banks (especially on the NF and SF Toutle). Reaches with mature conifers and no hydro-confinement were rated as a 1. Reaches with immature trees and/or stands of deciduous trees and no hydroconfinement were rated at 1.5. Reaches with visible areas of channel widening, bank failures, immature trees, hydroconfinement, etc were rated between a 2 and 3 depending upon the severity of each within the reach.

*Level of Proof*— There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*— In general, the template condition for wood in Lower Columbia River tributaries was assumed to be at an EDT rating of 0 for all areas except large canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind Rivers, which likely did not hold LWD as well. These areas were assumed to be at a rating of 1 to 2, based on the length and width of the canyon. For the Toutle watershed all reaches were given an EDT rating of 0 for the template condition except Hollywood Gorge. Hollywood Gorge is a narrow canyon, but not as pronounced as the canyon reaches mentioned above and was given an EDT rating of 1.

LWD counts were made during WDFW wild winter steelhead redd surveys (2003) in EDT reaches Cascade, Devils, Elk 1, Trouble, RB 2, and RB 3 using EDT protocol. No mainstem counts were done. EDT ratings were assumed to be 4 in all mainstem reaches, but, ratings were increased for Hollywood

Gorge, Green 2-8, SF Toutle 4-20 and Cascade Creek due to the large boulder habitat present in these areas. It was felt large boulder habitat acts as a partial surrogate for LWD in these areas. EDT ratings for LWD in surveyed tributary reaches averaged 3. Actual ratings were used in reaches where surveys were conducted and were assumed to be representative of the entire reach. All non-surveyed tributary reaches were assigned a value of 3, except Alder-A and NF Toutle 10 where LWD has been deposited due to the effects of the Sediment Retention Structure (SRS).

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

### Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (historic) condition, SW Washington watersheds were assumed to have fine sediment levels of 6%-11% (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3. The Toutle River enters the Cowlitz River at approximately river-mile 20, and is not tidally influenced. EDT reach Toutle-1 was given an EDT rating of 1. Silver Lake, however, was historically and continues to be a low-gradient wetland complex and is an area of sediment deposition. EDT reaches Silver Lake 1 & 2 were given an EDT rating of 4 for template and current conditions.

To rate the percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) examined the relationship between road density and fine sediment levels in coastal watersheds of Washington State's Olympic Peninsula region, and found that as road density increased by 1 km/sq.km fine sediment levels increased by 4.3% (2.65% per 1 mi./sq.mi.) However, Duncan and Ward (1985) found a lower increase in percentage of fines in southwest Washington, but attributed much of the variation in fines to different soil types. The Wind River is a Lower Columbia River tributary located in SW Washington and is likely representative of other watersheds in the region. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 mi/mi$^2$ of roads for all watersheds ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 mi/mi$^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored, was excluded. Rather than use all three years of Layout Creek data, only the median was used and the final relationship used for EDT was a 1.34% increase in fines per 1 mi/mi$^2$ ($R^2$=0.56, n=15) (Figure E7- 3).

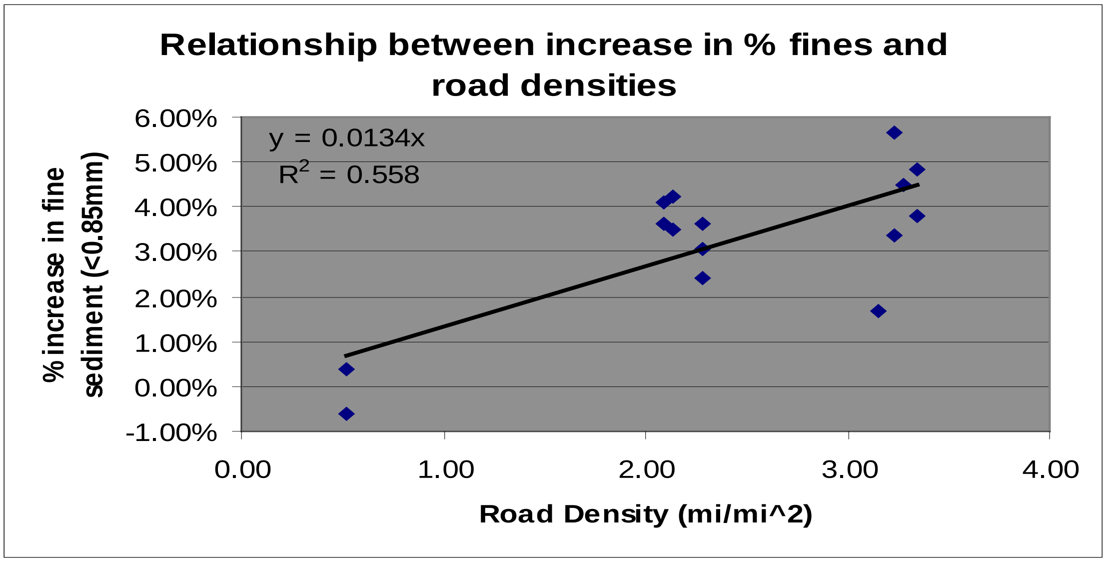


**Figure E7- 3.** **Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

Toutle River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries.Table E7-32 presents IWA road density by HUC for HUCs with associated EDT reaches and the corresponding EDT fine sediment rating.

**Table E7-32.** **IWA Road Densities for HUCS with Associated EDT Reaches and EDT Fine Sediment Ratings**

| LCFRB HUC # | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Fines Rating |
|---|---|---|---|
| 17080005030101 | Coldwater Cr | 2.1 | 1.58 |
| 17080005030201 | NF Toutle 13(.2) | 5.1 | 2.07 |
| 17080005030202 | NF Toutle 13(.3) | 5 | 2.06 |
| 17080005030205 | Castle Cr | 2.7 | 1.65 |
| 17080005030301 | Hoffstadt Cr 1(.75) | 5.3 | 2.05 |
| 17080005030302 | Hoffstadt Cr 1(.25), Hoffstadt Cr 2 | 6.7 | 2.25 |
| 17080005030303 | Alder Cr | 6 | 2.15 |
| 17080005030304 | NF Toutle 7, 8, 9, 10, 11, RB 8 | 6.6 | 2.25 |
| 17080005030305 | Bear Cr (NF Trib) | 7 | 2.35 |
| 17080005030306 | NF Toutle 12, 13(.5), Deer Cr | 5 | 2.06 |
| 17080005040201 | Green River 7, 8, 9, Tradedollar | 6.7 | 2.25 |
| 17080005040202 | Miners Cr | 3.6 | 1.8 |
| 17080005040203 | Shultz Cr 1, 2, Shultz Cr trib | 6.9 | 2.35 |
| 17080005040301 | Green River 6, Cascade Cr | 6.4 | 2.25 |
| 17080005040302 | Elk Cr 1, 2, Elk Cr trib | 6.5 | 2.25 |
| 17080005040401 | Green River 5(.5) | 6.6 | 2.25 |
| 17080005040402 | Green River 1, 2, 3, Beaver Cr, Jim Cr | 5.1 | 2.05 |
| 17080005040403 | Green River 4, Devil's Cr | 4.9 | 2.04 |
| 17080005040404 | Green River 5(.5) | 5.7 | 2.1 |
| 17080005050101 | SF Toutle 20, Disappointment Cr | 3 | 1.7 |
| 17080005050201 | SF Toutle 16, 17, 18, 19, RB 3, RB 4 | 6.4 | 2.25 |

| LCFRB HUC # | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Fines Rating |
|---|---|---|---|
| 17080005050202 | LB8, Trouble Cr | 6.1 | 2.18 |
| 17080005050301 | SF Toutle 11, 12, 13, Bear Cr(.5), Harrington Cr | 6.5 | 2.25 |
| 17080005050302 | SF Toutle 14, 15, LB 7, RB 2, Bear Cr(.5) | 5.9 | 2.15 |
| 17080005050401 | SF Toutle 4, 5, Brownell Cr 1, 2, Jordan, Thirteen, Eighteen | 6.5 | 2.25 |
| 17080005050402 | RB 10, Studebaker Cr 1, 2 | 6.7 | 2.25 |
| 17080005050403 | SF Toutle 2, 3, Johnson Cr | 7.1 | 2.35 |
| 17080005050404 | SF Toutle 6, 7, 8, LB 5, Twenty Cr, Big Wolf Cr | 5.7 | 2.1 |
| 17080005050405 | SF Toutle 9, 10, LB 6, Whitten Cr | 6 | 2.15 |
| 17080005070603 | Toutle 6, 7, 8, LB 4, RB 1 | 5.3 | 2.05 |
| 17080005070604 | Toutle 3, 4, 5, LB 2, LB 3, Stankey Cr, Rock Cr, Hollywood Gorge | 5.4 | 2.05 |
| 17080005070607 | Toutle 1, 2, LB 1 | 6.1 | 2.18 |
| 17080005070301 | NF Toutle 1, 2, 3, 4, 5, 6, RB 5, RB 6, RB 7, LB 9 | 7.1 | 2.35 |
| 17080005070302 | SF Toutle 1, LB 10, Wyant Cr 1, 2 | 6.7 | 2.25 |
| 17080005070401 | Toutle 9, Hemlock Cr 1, 2, RB 9, Silver Lake 1, Unnamed Lake trib | 4.5 | 1.95 |
| 17080005070402 | Silver Lake 2, Sucker Cr | 5.6 | 2.1 |
| 17080005070403 | Hemlock Cr 3 | 6.7 | 2.25 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In rating this attribute it was assumed that percent embeddedness is directly related to the percentage of fines in spawning gravel.

In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), it was assumed embeddedness was less than 10%, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. The Toutle River enters the Cowlitz River at approximately river-mile 20, and is not tidally influenced. EDT reach Toutle-1 was given an historical rating of 0.5. Silver Lake, however, was historically and continues to be a low-gradient wetland complex and is an area of sediment deposition. EDT reaches Silver Lake 1 & 2 were given an EDT rating of 4 for template and current conditions.

Using the USFS Wind River data and analysis described above for rating fine sediment, a scale was developed relating road density to percent embeddedness. This scale was used to generate embeddedness ratings for all EDT reaches in the watershed (with the exception of Silver Lake 1 & 2).

Toutle River watershed road density values were taken from IWA results for LCFRB subwatersheds (HUCs) (LCFRB 2003). EDT reaches were linked to the appropriate HUC(s) by examining a map of HUC boundaries. Table E7-33 presents IWA road density by HUC for HUCs with associated EDT reaches and the corresponding EDT embeddedness rating.

**Table E7-33. IWA Road Densities for HUCS with Associated EDT Reaches and EDT Embeddedness Ratings.**

| LCFRB HUC | EDT Reaches associated with HUCS | HUC Road Density (mi./sq.mi.) | Wind Relationship-EDT Emb. Rating |
|---|---|---|---|
| 17080005030101 | Coldwater Cr | 2.1 | 0.6 |
| 17080005030201 | NF Toutle 13(.2) | 5.1 | 0.8 |
| 17080005030202 | NF Toutle 13(.3) | 5 | 0.8 |
| 17080005030205 | Castle Cr | 2.7 | 0.65 |
| 17080005030301 | Hoffstadt Cr 1(.75) | 5.3 | 0.81 |
| 17080005030302 | Hoffstadt Cr 1(.25), Hoffstadt Cr 2 | 6.7 | 0.9 |
| 17080005030303 | Alder Cr | 6 | 0.85 |
| 17080005030304 | NF Toutle 7, 8, 9, 10, 11, RB 8 | 6.6 | 0.9 |
| 17080005030305 | Bear Cr (NF Trib) | 7 | 0.94 |
| 17080005030306 | NF Toutle 12, 13(.5), Deer Cr | 5 | 0.8 |
| 17080005040201 | Green River 7, 8, 9, Tradedollar | 6.7 | 0.9 |
| 17080005040202 | Miners Cr | 3.6 | 0.71 |
| 17080005040203 | Shultz Cr 1, 2, Shultz Cr trib | 6.9 | 0.94 |
| 17080005040301 | Green River 6, Cascade Cr | 6.4 | 0.89 |
| 17080005040302 | Elk Cr 1, 2, Elk Cr trib | 6.5 | 0.9 |
| 17080005040401 | Green River 5(.5) | 6.6 | 0.9 |
| 17080005040402 | Green River 1, 2, 3, Beaver Cr, Jim Cr | 5.1 | 0.8 |
| 17080005040403 | Green River 4, Devil's Cr | 4.9 | 0.79 |
| 17080005040404 | Green River 5(.5) | 5.7 | 0.84 |
| 17080005050101 | SF Toutle 20, Disappointment Cr | 3 | 0.67 |
| 17080005050201 | SF Toutle 16, 17, 18, 19, RB 3, RB 4 | 6.4 | 0.89 |
| 17080005050202 | LB8, Trouble Cr | 6.1 | 0.87 |
| 17080005050301 | SF Toutle 11, 12, 13, Bear Cr(.5), Harrington Cr | 6.5 | 0.9 |
| 17080005050302 | SF Toutle 14, 15, LB 7, RB 2, Bear Cr(.5) | 5.9 | 0.86 |
| 17080005050401 | SF Toutle 4, 5, Brownell Cr 1, 2, Jordan, Thirteen, Eighteen | 6.5 | 0.9 |
| 17080005050402 | RB 10, Studebaker Cr 1, 2 | 6.7 | 0.9 |
| 17080005050403 | SF Toutle 2, 3, Johnson Cr | 7.1 | 0.94 |
| 17080005050404 | SF Toutle 6, 7, 8, LB 5, Twenty Cr, Big Wolf Cr | 5.7 | 0.84 |
| 17080005050405 | SF Toutle 9, 10, LB 6, Whitten Cr | 6 | 0.85 |
| 17080005070603 | Toutle 6, 7, 8, LB 4, RB 1 | 5.3 | 0.81 |
| 17080005070604 | Toutle 3, 4, 5, LB 2, LB 3, Stankey Cr, Rock Cr, Hollywood Gorge | 5.4 | 0.81 |
| 17080005070607 | Toutle 1, 2, LB 1 | 6.1 | 0.87 |
| 17080005070301 | NF Toutle 1, 2, 3, 4, 5, 6, RB 5, RB 6, RB 7, LB 9 | 7.1 | 0.94 |
| 17080005070302 | SF Toutle 1, LB 10, Wyant Cr 1, 2 | 6.7 | 0.9 |
| 17080005070401 | Toutle 9, Hemlock Cr 1, 2, RB 9, Silver Lake 1, Unnamed Lake trib | 4.5 | 0.78 |
| 17080005070402 | Silver Lake 2, Sucker Cr | 5.6 | 0.83 |
| 17080005070403 | Hemlock Cr 3 | 6.7 | 0.9 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process that occasionally increased turbidity after an extensive hot burn. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels at an EDT rating of 0 in small tributaries (<35 ft. ww-high), 0.3 in medium tributaries (>35 ft. ww-high), and 0.5 in mainstem reaches.

Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (2004). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout Creek, Panther Creek, and the Middle Wind are over 40 mg/L, and other basins are 5-40mg/L with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If suspended sediment levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L levels last 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support EDT ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for lower mainstem reaches.

These rules were used to generate ratings for all reaches in the historic condition and for all but the Toutle and NF Toutle mainstem reaches in the current condition. The Mount St. Helen's eruption buried much of the NF, SF and mainstem Toutle in mud and debris. Currently, the SF Toutle has flushed itself of much of the sediment from the mud avalanche. The SRS on the NF Toutle was designed to capture mud and debris flushing from the upper NF Toutle (Loch et al.1990). Mud stored behind the SRS provides a consistent source of sediment input into the lower NF and mainstem Toutle. Turbidity ratings were calculated separately for the mainstem Toutle reaches, NF Toutle reaches below the SRS, and NF Toutle reaches above the SRS.

Current turbidity ratings for the mainstem Toutle were generated from USGS suspended sediment and streamflow data collected at the gauge station near Tower Road (USGS 2004). The data set was queried for entry dates where both suspended sediment data and streamflows were available. Prior to 1997, sediment data was either pre-eruption of Mount St. Helens or in the mid to late 1980s when the system was still experiencing extreme sediment loads from the eruption. Data from these years is likely not representative of current conditions and was not used in this analysis. Suspended sediment data (mg/l) from 1997 – 2002 was plotted versus streamflow (cfs). A trend line fit to the dataset ($R^2 = 0.27$) generated the linear equation: y=0.491x+283.3 (where y= suspended sediment (mg/l), 0.491 = slope, x = streamflow (cfs), and 283.3 = y-intercept). Using this equation and mean monthly flow data for the Toutle gauge at Tower Road (USGS 2004) average suspended sediment values by month were calculated. In turn, suspended sediment (mg/l) values were applied to the SEV index utilizing the equation described above (Turbidity: definition). Since suspended sediment values were calculated as monthly averages, duration was assumed to be 1 month or 744 hours (24 hours x 31 days). SEV Index values were used to develop EDT ratings by month according to EDT guidelines. The highest EDT rating was entered into the model and the corresponding month was identified as the focus month. EDT ratings for all months were used to generate a monthly shape pattern for this attribute.

Turbidity ratings for the NF Toutle below the SRS were derived from mainstem Toutle suspended sediment values. Water discharged from the Green River, SF Toutle and NF Toutle watersheds flow together to produce the majority of flow in the mainstem Toutle River, while the majority of sediment discharged into the mainstem Toutle comes from the North Fork. USGS gauge data (2004) was queried to acquire mean monthly flow values for the Green River gauge near Toutle, the NF Toutle gauge at Kid Valley, and the SF Toutle gauge at Toutle. Monthly flows from these three systems were summed (by month) and the percentage of flow attributable to the NF Toutle was calculated. It was assumed that suspended sediment levels in the NF Toutle are diluted by flows from the Green River and SF Toutle before reaching the Tower Road gauge. Average monthly suspended sediment values calculated for the mainstem Toutle were divided by the percentage of flow attributable to the NF Toutle to estimate suspended sediment values for the NF Toutle below the SRS. Following the same methods used for the Toutle, SEV Index values, EDT ratings and monthly patterns were developed.

Turbidity ratings for NF Toutle above the SRS were adjusted from ratings below the SRS based on professional knowledge of the area. Much of the mud and debris from the Mount St. Helens eruption has been flushed from the upper North Fork, as evidenced by the material captured by the SRS. It was assumed that during low flow months turbidity in the upper NF Toutle is much less than in areas below the SRS, but during high flow events sediment continues to be flushed from the watershed. The maximum EDT rating and focus month from below the SRS was applied to reaches above the SRS, but a separate monthly shape pattern was created for the upper North Fork reflecting reduced turbidity during low flow months.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Historical temperatures are unknown the in the Toutle River subbasin. The only historical temperature data that was located were temperatures recorded in the 1930’s and 40’s while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary processes transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2000). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches can be estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next, it was assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these tress are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, 49 meters was used as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, the relationship between forest angle and percentage of shade was used (WFPB 1997 Appendix G-33). Finally, the relationship between elevation, percentage of shade and the maximum daily stream temperature was used to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams, our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. A correction factor was developed for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

For current conditions, the EDT maximum temperature calculator (MS Access) provided by Mobrand Biometrics, Inc. (MBI) was used to generate ratings for reaches where temperature data was available.

Temperature data corresponding to summertime low flows (August) was limited for the Toutle River watershed. Table E7-34 lists the EDT reaches where temperature data was available and the data source. Temperature data collected within an EDT reach was assumed to be representative of the entire reach and was used to generate an EDT rating for the reach. Ratings for mainstem reaches without temperature data were extrapolated based on elevation, and proximity to reaches with temperature data.

**Table E7-34. Toutle River EDT reaches with August temperature data & data source.**

| EDT Reach | Temperature Data Source |
|---|---|
| Green 1 | WDFW North Toutle Salmon Hatchery |
| Harrington Creek | Timber/Fish/Wildlife (Sullivan et al, 1990) |
| Hoffstadt Creek | Timber/Fish/Wildlife (Sullivan et al, 1990) |
| Schultz Creek | Timber/Fish/Wildlife (Sullivan et al, 1990) |
| SF Toutle 2 | SF gauge @ Camp 12 (USGS 2004) |
| Silver Lake 1 & 2 | Silver Lake Phase II Study (Scherer 1996) |

EDT maximum temperature ratings for Harrington, Hoffstadt and Schultz Creeks in the current condition were compared to historic ratings generated by the "shade" model. Ratings in the current condition were found to be 1.5 points higher than historic for Harrington creek, a forested tributary, and an average of 1.8 points higher for Hoffstadt and Schultz Creeks, tributaries deforested by the Mount St. Helens eruption. By using ortho-photos via GIS, this relationship was used to develop ratings for tributary reaches without temperature data. Exceptions to this were tributaries from Johnson Creek upstream on the SF Toutle and Elk, Devils, Beaver, and Jim Creeks on the Green River, where Harrington creek was thought to be an appropriate surrogate and Harrington Creek ratings (current condition) were used.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Minimum temperature data was lacking in the basin. Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) –5.8305 ( $R^2$= 0.32, n=27). This relationship was used to generate categorical ratings (Table E7-35) based on elevation.

**Table E7-35. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

Minimum temperature ratings were assigned to both the historical and current conditions. Tributary ratings were assigned based on the elevation at the mouth unless they have more than one reach. In this case, elevations within each reach were used.

*Level of Proof*— A combination of expanded empirical observations, derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—No data was found regarding current or historical conditions for groundwater inputs in this basin. Historically, there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries in the upper watershed likely had less groundwater input. These reaches were given an EDT rating of 2. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either $HCO_3$ or $CaCO_3$.

*Rationale*—Alkalinity was estimated from historical USGS (2004) data for conductivity using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). Conductance data was limited in the Toutle River watershed. Most USGS data was collected in the year after the eruption of Mount St. Helens when sediment levels/turbidity were extremely high, which elevated specific conductance values. This data was not used. USGS conductance data prior to the eruption was available for the USGS Toutle River gauge near Castle Rock. This data translated to an alkalinity value of 26.7 or an EDT rating of ~2.1. Specific conductance data was available from three stations on the Coweeman; alkalinity = 31.5 or an EDT rating of 2.2. Specific conductance data for three Weyerhaeuser diversion ponds fed by Sucker Creek translated to an alkalinity of 45 or an EDT rating of ~2.25 (Beak Consultants 1998). A rating of 2.1 was applied to the entire Toutle River watershed except for Sucker creek, which was rated at 2.25. One sample from USGS data was available for Silver Lake, which indicated the lake may have an alkalinity value of 12 (EDT =1.6), however ratings were left at 2.1 for Silver Lake reaches. Alkalinity in the historic condition was given the same rating as the current condition for all reaches.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired, an EDT rating of 0 (>8mg/l in August). Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. USGS (2004) dissolved oxygen data is limited post 1980 (after Mount St. Helens eruption). Prior to 1980, USGS sampling within the Toutle River watershed indicated dissolved oxygen levels were >8 mg/l. For the current condition, an EDT rating of 0 was given to all reaches.

*Level of Proof*— A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because, of the lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically, nutrient enrichment did not occur because, by definition, watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches under current conditions the following factors were examined: fertilizing by timber companies, reaches downstream from fish hatcheries, agriculture effects, septic tanks, and storm water run-off.

Most of the NF Toutle, SF Toutle and Green River sub-basins are owned by Weyerhaeuser and managed for timber harvest. Other than the Kid Valley area on the NF Toutle, stream adjacent homes in these areas are rare. Weyerhaeuser utilizes the following protocol for fertilizing the Mount St. Helens North and South Tree Farms (pers. com. Byron Richert, Weyerhaeuser): fertilizer is applied aerially (via helicopter), the fertilizer used is Urea 46-00-0 applied at 440 lbs./acre (210 lbs. active Nitrogen), only Douglas Fir responsive stands (>50% Douglas Fir) are fertilized, fertilization starts at age 18 and is conducted once every seven years until three years before harvest. The effects of this fertilization on stream enrichment are likely difficult to measure, but were assumed to be minimal. The WDFW North Toutle Salmon Hatchery is located at the top of EDT reach Green-1 (downstream reach = NF Toutle-6). Some nutrient enrichment likely occurs from hatchery operations. Enrichment from a hatchery acclimation pond located on Brownell creek was thought to be minimal due to the short duration of its operation annually. Most enrichment, other than from hatchery operations, likely occurs from sporadic stream adjacent homes along the mainstem Toutle River via septic systems and small-scale agriculture. The town of Toutle is located near Hemlock (Outlet) Creek and has a sewage treatment/disposal site near the creek. EDT reaches Green-1 and NF Toutle 1-6 were rated at a 1 due to homes and hatchery operations. Hatchery effects are likely diluted at the confluence of the NF and SF Toutle. Toutle 1-9 and Hollywood Gorge were rated at a 0.5 due to upstream hatchery effects, stream adjacent homes (septic), inputs from the Silver Lake watershed, and agriculture. Studebaker 1(SF Trib.) and Wyant 1 (NF Trib) have low gradient reaches with stream adjacent homes and some agriculture. These reaches were rated at 0.5. All other reaches of the NF Toutle, SF Toutle, and Green Rivers were rated at 0.

Nutrient enrichment levels are likely increased in the Silver Lake watershed, which is heavily populated with lake adjacent homes. Wade (2000) states: "The natural phosphorus and nitrogen levels in soils within the Silver Lake watershed are comparatively high. Both applications of forest fertilizer and residential septic systems are likely contributors to elevated nitrogen and phosphorus levels within the watershed (Weyerhaeuser 1994; Houpt et al. 1994)". Results of a Weyerhaeuser study found Silver Lake is in an advanced state of eutrophication (Weyerhaeuser 1994). EDT reaches Silver Lake 1 & 2 and Hemlock (Outlet) Creek 1 & 2 were rated at a 1.5. Hemlock creek 3 and Unnamed Lake tributary were rated at 0. The Weyerhaeuser Headquarter Camp/ Solid Waste Facility is located on Sucker Creek; Sucker Creek was rated at 0.5.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

## Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*— Historical fish community richness was estimated from the current distribution of native fish in these watersheds. Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness in SW Washington watersheds was estimated from direct observation (stream surveys, snorkel surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, local knowledge, and expert opinion. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer, which was captured in the EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Abernathy, Germany, and Mill creeks (pers. com. Hanratty, WDFW), (2) electro-shocking in 2002 by USFWS in Abernathy Creek (pers. com. Zydlewski, USFWS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW stream & snorkel surveys on the Elochoman (pers. com. Byrne, WDFW), Kalama, East Fork Lewis, Toutle and Coweeman Rivers, (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls).

The Toutle River enters the Cowlitz River above tidal influence. Non-native species from the Lower Columbia River that are often found in the lower, tidally influenced reaches of its tributaries are not as likely to penetrate into the Toutle system, but may exist at some level. The exact number of these species and their distribution have not been documented and were not included when rating this attribute. Generally, historic and current fish community richness in the Toutle Basin were assumed to be similar and the above sources were used to develop EDT ratings. An exception to this is the Silver Lake watershed. Silver Lake received historic plants of many warmwater fish species (WDF), which are now self-sustaining. In the late 1990s grass carp (sterile) were introduced into the lake to control aquatic vegetation. Currently, the lake receives annual plants of rainbow trout. These fish can potentially exit the lake via the fish ladder at the Silver Lake Dam and warmwater species have been found in Outlet Creek (EDT reaches Hemlock 1& 2). A weir just below the dam has been constructed to prevent grass carp from emigrating from the lake (pers. com. Kelsey, WDFW and Manlow, WDFW). Current fish community richness in the Silver Lake Watershed was estimated from surveys conducted by Lavier (1973) and Caromile & Jackson (2000).

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate both the historic and current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute’s rating for watersheds in pristine condition. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

The WDFW North Toutle Hatchery (located at top of EDT reach - Green 1) releases early coho, fall Chinook, and summer steelhead, annually. In addition, the Cowlitz Game and Anglers club operates an acclimation pond on Brownell Creek (EDT reach Brownell 1) for summer steelhead released into the SF Toutle. (pers. com. Dammers, WDFW). Silver lake receives an annual plant of approximately 10,000 rainbow trout for a put-and-take fishery (pers. com. Kelsey, WDFW). These fish potentially can move down through Outlet Creek (EDT reaches Hemlock 1 & 2) into the mainstem Toutle. Green 1 and reaches downstream (NF Toutle 1-6 and all mainstem Toutle reaches) were rated at a 4, Green 2, SF Toutle 1-4, Brownell 1, Silver Lake 1 & 2 and Hemlock 1 & 2 (Outlet Creek) were rated at a 2.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and pathogen levels were assumed to be at background levels. All reaches were given an EDT rating of 0.

The WDFW North Toutle Hatchery is the divider between EDT reaches Green 1 & 2, and releases early coho, fall Chinook, and summer steelhead, annually.

These reaches and NF Toutle 6 (downstream reach from Green 1) were given an EDT rating of 3. In addition, the Cowlitz Game and Anglers club operates a summer steelhead acclimation pond in EDT reach Brownell 1, which flows into SF Toutle 3 (pers. Com. Dammers, WDFW). Silver lake receives an annual plant of approximately 10,000 rainbow trout for a put-and-take fishery (pers. com. Kelsey, WDFW). These fish potentially can move down through Outlet Creek (EDT reaches Hemlock 1 & 2) into the mainstem Toutle. SF Toutle 1-4, Brownell 1, NF Toutle 1-5, Silver Lake 1&2, Hemlock 1&2 (Outlet Creek), Toutle 1-9 and Hollywood Gorge were given an EDT rating of 2 . All other reaches were given an EDT rating of 0.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute's rating for watersheds in pristine condition.

Utilizing GIS, the SSHIAP and DNR roads layers, DNR digital ortho-photos, and USGS topography maps (1:24,000) were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use; a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; a rating of 2 was given to reaches with multiple access points (or road parallels reach) through public lands or unrestricted access through private lands; a rating of 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands; and a rating of 0 was given to reaches far from population centers with no roads.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute's rating for watersheds in pristine condition.

The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species (i.e. birds) is unknown in these watersheds.

The WDFW North Toutle Hatchery releases early coho, fall Chinook and summer steelhead. Summer steelhead are also acclimated and released on Brownell Creek. Silver Lake receives annual plants of rainbow trout. Hatchery releases potentially increase predation on native fish. Populations of non-native piscivorous fish from the Lower Columbia River and Lower Cowlitz River may exist in the lower reaches of the Toutle River, although the Toutle is above tidal influence and the exact number of these species and their distribution has not been documented. Also, plants of hatchery coho and steelhead from Cowlitz River hatcheries may utilize the mouth and lowest reach of the Toutle River adding to the potential for predation. Silver Lake supports populations of several non-native warm water species from historic fish plants. These species and planted rainbow trout can escape the lake and have been found in Outlet Creek (Hemlock 1&2), and may also enter the mainstem Toutle River. Toutle 1-9, Hollywood Gorge, SF 1-4, Brownell 1, Green 1&2, NF 1-6 , Silver Lake 1&2, and Hemlock 1&2 (Outlet Creek) were given increased ratings for predation. All other reaches were given a rating of 2.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Mainstem reaches with historic chum presence (spawning) were given a rating of 0 (super abundant, >800). Mainstem reaches with Chinook and coho, but no chum, were given a rating of 2 (moderately abundant, >200 and <400). Reaches with only coho were given a rating of 3 (not abundant, >25 and <200). Reaches with only steelhead and/or cutthroat trout were given a rating of 4 (very few or none, <25), since these fish can spawn more than once (iteroparous). Tidal reaches below areas of chum spawning were given a rating of 1 (very abundant, >400 and <800); it was assumed carcasses from spawning reaches above are washed into these reaches.

An estimate of the current number of salmon carcasses per mile was derived from natural spawn escapement estimates, weir/trap counts, EDT reach length data, and SSHIAP fish distribution data. SSHIAP categorizes fish distribution into known, presumed, and potential habitat by species, and EDT reaches were delineated using these categories during development of the EDT template. Using potential fish distribution, EDT reach lengths were summed to develop the total number of miles of habitat available for each species. Where available, the natural spawn escapement estimate was divided by the corresponding number of miles of habitat to generate the average number of carcasses per mile for each species. These values were summed according to the species present within each reach to develop an estimate of the total number of carcasses per mile within the reach. Calculations were completed for chum, Chinook and coho only, as steelhead and cutthroat trout are iteroparous and likely contribute few carcasses. When escapement data was not available, expert opinion was used to estimate carcass abundance.

The Toutle River currently supports naturally produced populations of fall Chinook, coho, winter steelhead and cutthroat trout. Chum may exist in low numbers, but fall stream surveys, and trap counts at the North Toutle Salmon Hatchery and the Toutle Collection Facility (TCF) have recovered/trapped few, if any, chum. In addition, the WDFW North Toutle Salmon Hatchery releases fall Chinook, early coho and summer steelhead. The majority of hatchery origin fall Chinook and coho return to the Green River, however, straying into the SF Toutle likely occurs. Natural spawn escapement estimates for fall Chinook are available from WDFW stream surveys for the Green and SF Toutle, and a ten-year average (1992-2001) of 1021 and 93, respectively, was used for calculating carcass abundance. A weir installed annually at the North Toutle Salmon Hatchery during fall salmonid returns provides a means of enumerating returning adult coho passed upstream on the Green River. The weir is not 100% effective at blocking fish passage. High water events, weir undermining and controlled weir openings can allow fish to pass uncounted, therefore weir counts were considered minimum estimates of Green River coho escapement, and carcass abundance estimates may be biased low; an eight-year average (1994-2001) of 9541 coho was used for calculations. The Sediment Retention Structure (SRS) is an impassable barrier to returning adults and is located at the top of NF Toutle 9. The TCF, located at the top of NF Toutle 7, traps returning adult fish. Only coho and wild steelhead are trucked upstream and released into Alder and Hoffstadt Creeks. Chinook and hatchery steelhead are returned downstream or trucked to the North Toutle Hatchery. Densities of coho transported above the SRS are low; a seven-year average (1997-2003) of 295 coho was used for calculating carcass abundance above the SRS. Coho escapements are not available for the SF Toutle, but numbers/carcass densities are thought to be low. Escapement estimates for the mainstem Toutle, its tributaries and the Silver Lake watershed were not available, but densities are thought to be low.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the historic and current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. This rating was used as a baseline for benthos diversity and was assigned to all reaches for historic conditions.

Current Wind River data indicates EDT scores in disturbed Rosgen B-channels are similar to historic scores of 0.6 and in disturbed C-channels scores are reduced to 1.3. The Mount St. Helen's eruption buried much of the NF, SF and mainstem Toutle in mud and debris. Macroinvertebrate abundance and diversity was likely severely impacted. High sediment loads in the NF and mainstem Toutle River provide for continual deposition of sediment over substrate that macroinvertebrates might use. Diversity and abundance of macroinvertebrates were found to be higher below the Toutle Collection Facility (TCF) (NF Toutle) and on the Green River, than in the upper NF Toutle. Areas of the upper NF Toutle that were most heavily impacted by the Mount St. Helen's mud flow had the lowest macroinvertebrate abundance and diversity (pers com. Loch WDFW). Loch (WDFW) found a diverse group of macroinvertebrates on Maretta Creek (NF tributary) that may be providing recruitment to the NF Toutle. Currently, the SF Toutle has flushed itself of much of the sediment from the mud avalanche. Accordingly, macroinvertebrate abundance and diversity is most likely recovering. Tributaries unaffected by the Mount St. Helen's eruption are a likely source of macroinvertebrate recruitment. The mainstem Toutle, NF Toutle, and SF Toutle 1&2 were given a rating of 1.5. Disturbed reaches of lower Studebaker, Wyant, and Johnson were rated at a 1.5. NF 10 & 11 and the lower reaches of Alder Creek are buried in sediment that has collected behind the SRS. These reaches were rated at a 4. All other reaches were rated at 0.6.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, derived information, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Expansion of empirical observations, and expert opinion were used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

**Acknowledgements**

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Weyerhaeuser for access to these streams for spawning ground surveys and to collect habitat data used in this modeling effort. We thank the staff at Mobrand Biometric for running the model especially Kevin Malone and Jennifer Garrow.

| | **Appendix C: EDT reaches and descriptions** |
|---|---|
| **EDT Reach** | **EDT Reach Description** |
| Alder Creek A | Description: mouth upstream approximately 1.3 miles to road crossing. |
| Alder Creek B | Description: road crossing at ~1.3 miles to RM 6.4 |
| Bear Creek | Description: mouth to RM 2.5 (includes small LB trib); Confinement: confined; Fish Species present: WS presumed |
| Bear Creek (NF Trib.) | Description: mouth to RM  3.8 ; Confinement: unconfined; Fish Species Present : WS |
| Beaver Creek | Description: mouth to forks (in beaver pond); Confinement: confined to moderate; Fish Species present: WS presumed |
| Big Wolf Creek | Description: mouth to RM 0.2; Confinement: confined; Fish Species present: WS |
| Brownell Creek 1 | Description: mouth to Jordan Creek; Confinement: moderate; Fish Species present: WS—0.1 known, 0.3 potential |
| Brownell Creek 2 | Description: Jordan Creek to light-duty road; Confinement: moderate to unconfined; Fish Species present: WS potential |
| Cascade Creek | Description: mouth to fork at RM 1.2; Confinement: confined; Fish Species present: WS |
| Castle Creek | Description: mouth to end of available habitat; Confinement: unconfined to moderate; Fish Species Present: WS (presumed) |
| Coldwater Creek | Description: mouth to end of available habitat; Confinement: unconfined to moderate; Fish Species Present: WS (presumed) |
| Deer Creek | Description: mouth to RM 1.6; Confinement: moderate; Fish Species Present: WS |
| Devils Creek | Description: mouth to fork at RM 5; Confinement: confined; Fish Species present: WS |
| Disappointment Cr | Description: mouth to fork to 0.5 up left fork, 0.8 up right fork; Confinement: moderate; Fish Species present: WS—0.8 known, 0.7 presumed |
| Eighteen Creek | Description: mouth to fork; Confinement: confined; Fish Species present: WS |
| Elk Cr trib | Description: mouth to road crossing; Confinement: confined to moderate; Fish Species present: WS |
| Elk Creek 1 | Description: mouth to RB trib at RM 2.5; Confinement: confined; Fish Species present: WS |
| Elk Creek 2 | Description: RB trib to fork at RM 5; Confinement: confined; Fish Species present: WS presumed |
| Green River 1 | Description: mouth to hatchery intake; Confinement: moderate to confined; Fish Species present: WS, FC, SC |
| Green River 2 | Description: hatchery intake to Beaver Creek; Confinement: confined; Fish Species present: WS, FC, SC |
| Green River 3 | Description: Beaver Creek to Jim Creek; Confinement: confined; Fish Species present: WS, FC, SC |
| Green River 4 | Description: Jim Creek to Devils Creek; Confinement: confined; Fish Species present: WS, FC, SC |
| Green River 5 | Description: Devils Creek to Cascade Creek; Confinement: confined; Fish Species present: WS, FC, SC |
| Green River 6 | Description: Cascade Creek to Elk Creek; Confinement: moderate; Fish Species present: WS, FC, SC |
| Green River 7 | Description: Elk Creek to Shultz Creek; Confinement: moderate; Fish Species present: WS, FC, SC |
| Green River 8 | Description: Schultz Creek to Tradedollar Creek; Confinement: moderate to confined; Fish Species present: WS, FC, SC |
| Green River 9 | Description: Tradedollar Creek to Miners Creek; Confinement: moderate to confined; Fish Species present: WS, SC for 0.6 mile of this reach to RM 25 |
| Harrington Creek | Description: mouth to RM 1.5; Confinement: confined; Fish Species present: WS |
| Hemlock Cr 1 | Description: mouth to unnamed RB trib9; Confinement: unconfined to moderate; Fish Species present: WS, FC presumed |
| Hemlock Cr 2 | Description: unnamed RB trib9 to Silver Lake; Confinement: unconfined; Fish Species present: WS, FC presumed |
| Hemlock Cr 3 | Description: Silver Lake to end of anadromous presence; Confinement: unconfined to moderate; Fish Species present: WS, FC |
| Hoffstadt Cr 1 | Description: mouth to Bear Creek; Confinement: Unconfined; Fish Species Present: WS |
| Hoffstadt Cr 2 | Description: Bear Creek to Forks; Confinement: moderate to confined; Fish Species Present: WS |

| | **Appendix C: EDT reaches and descriptions** |
|---|---|
| Hollywood Gorge | Description: Rock Creek to head of Gorge; Confinement: confined; Fish Species present: CH, WS, FC, SC |
| Jim Creek | Description: mouth to increased gradient (end of beaver ponds); Confinement: confined; Fish Species present: WS—0.5 known, 1.0 potential |
| Johnson Creek | Description: mouth top extent of distribution (includes small tribs); Confinement: unconfined to moderate; Fish Species present: FC—1.2 known; 'WS—3.3 known, 2.5 presumed, 0.75 potential |
| LB trib1 (26.0228) | Description: mouth to fork, to culvert (road) on right fork, to pond on left fork; Confinement: moderate to confined; Fish Species present: WS presumed |
| LB trib10 (not listed) | Description: mouth to limit of steelhead presence (including potential) (includes both forks at headwaters); Confinement: unconfined to confined; Fish Species present: WS—2.6 known, 1.9 potential, 0.7 presumed |
| LB trib2 (26.0229) | Description: mouth to RM 1.3; Confinement: confined; Fish Species present: WS |
| LB trib3 (26.0235) | Description: mouth to RM 1.8; Confinement: moderate to confined; Fish Species present: WS—0.8 known, 1.0 potential |
| LB trib4 (not listed) | Description: mouth to limit of sthd dist.; Confinement: unconfined to moderate; Fish Species present: WS—0.7 known, 1.8 presumed |
| LB trib5 (not listed) | Description: mouth to RM 0.2; Confinement: confined; Fish Species present: WS presumed |
| LB trib6 (not listed) | Description: mouth to RM 1.2; Confinement: confined; Fish Species present: WS presumed |
| LB trib7 (not listed) | Description: mouth to RM 3 (includes small LB trib; Confinement: confined; Fish Species present: WS presumed |
| LB trib8 (not listed) | Description: mouth to RM 1.0; Confinement: moderate; Fish Species present: WS presumed |
| LB trib9 (not listed) | Description: mouth to fork; Confinement: moderate; Fish Species present: WS potential |
| Lower Cowlitz-1 | Cowlitz R from the Columbia R to Coweeman R |
| Lower Cowlitz-2 | Cowlitz R from Coweeman R to Toutle R |
| Miners Creek | Description: mouth to increased gradient; Confinement: moderate to confined; Fish Species present: WS |
| NF Toutle 1 | Description: mouth to Wyant Creek; Confinement: unconfined; Fish Species present: CH, WS, FC, SC |
| NF Toutle 10 | Description: SRS to Alder Creek; Confinement: unconfined; Fish Species present: WS, FC, SC |
| NF Toutle 11 | Description: Alder Creek to Hoffstadt Creek; Confinement: unconfined; Fish Species present: WS, FC, SC |
| NF Toutle 12 | Description: Hoffstadt Creek to Deer Creek; Confinement: unconfined; Fish Species present: WS, FC, SC |
| NF Toutle 13 | Description: Deer Creek to Coldwater Creek outlet and Castle Creek (opposite each other); Confinement: unconfined to moderate; Fish Species present: WS, FC, SC |
| NF Toutle 2 | Description: Wyant Creek to unnamed RB trib5; Confinement: unconfined; Fish Species present: CH, WS, FC, SC |
| NF Toutle 3 | Description: unnamed RB trib5 to unnamed RB trib6; Confinement: moderate to confined; Fish Species present: CH, WS, FC, SC-chum drop out at half this reach |
| NF Toutle 4 | Description: unnamed RB trib6 to unnamed LB trib9 (about RM 7 at stream gauge); Confinement: confined; Fish Species present: WS, FC, SC |
| NF Toutle 5 | Description: unnamed LB trib9 to unnamed RB trib7 (at 19 mile camp); Confinement: confined; Fish Species present: WS, FC, SC |
| NF Toutle 6 | Description: unnamed RB trib7 to Green River; Confinement: moderate; Fish Species present: WS, FC, SC |
| NF Toutle 7 | Description: Green River to Fish Trap; Confinement: unconfined; Fish Species present: WS, FC, SC |
| NF Toutle 8 | Description: Fish Trap to unnamed RB trib8; Confinement: moderate; Fish Species present: WS, FC, SC |
| NF Toutle 9 | Description: unnamed RB trib8 to sediment retention structure; Confinement: moderate; Fish Species present: WS, FC, SC |

| | **Appendix C: EDT reaches and descriptions** |
|---|---|
| RB trib1 (26.0237) | Description: mouth to RM 2.2; Confinement: unconfined to moderate; Fish Species present: WS—0.5 known, 1.0 presumed, 0.7 pot. |
| RB trib10 (not listed) | Description: mouth to road crossing; Confinement: moderate to confined; Fish Species present: WS presumed |
| RB trib2 (not listed) | Description: mouth to RM 1.3; Confinement: confined; Fish Species present: WS |
| RB trib3 (not listed) | Description: mouth to RM 0.5; Confinement: moderate; Fish Species present: WS |
| RB trib4 (not listed) | Description: mouth to RM 1.5; Confinement: moderate; Fish Species present: WS—0.5 known, 1.0 presumed |
| RB trib5 (not listed) | Description: mouth to RM 1.2; Confinement: unconfined to confined; Fish Species present: WS presumed |
| RB trib6 (not listed) | Description: mouth to extent of available habitat (includes small tribs); Confinement: moderate to confined; Fish Species present: WS potential |
| RB trib7 (26.0320) | Description: mouth to increased gradient; Confinement: unconfined; Fish Species present: WS |
| RB trib9 (not listed) | Description: mouth to fork; Confinement: unconfined; Fish Species present: WS potential |
| Rock Creek | Description: mouth to headwaters; Confinement: unconfined to moderate; Fish Species present: WS—0.6 known, 1.8 potential |
| SF Toutle 1 | Description: mouth to Studebaker Creek; Confinement: unconfined; Fish Species present: CH, WS, FC, SC |
| SF Toutle 10 | Description: unnamed LB trib6 to Whitten Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 11 | Description: Whitten Creek to Bear Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 12 | Description: Bear Creek to Harrington Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 13 | Description: Harrington Creek to unnamed LB trib7; Confinement: confined; Fish Species present: WS, SC |
| SF Toutle 14 | Description: unnamed LB trib7 to unnamed RB trib2; Confinement: confined; Fish Species present: WS, SC |
| SF Toutle 15 | Description: unnamed RB trib2 to Trouble Creek; Confinement: confined; Fish Species present: WS, SC |
| SF Toutle 16 | Description: Trouble Creek to unnamed LB trib8; Confinement: confined; Fish Species present: WS, SC |
| SF Toutle 17 | Description: unnamed LB trib8 to unnamed RB trib3; Confinement: moderate; Fish Species present: WS, SC |
| SF Toutle 18 | Description: unnamed RB trib3 to unnamed RB trib4; Confinement: moderate; Fish Species present: WS, SC |
| SF Toutle 19 | Description: unnamed RB trib4 to Disappointment Creek; Confinement: moderate to confined; Fish Species present: WS, SC |
| SF Toutle 2 | Description: Studebaker Creek to Johnson Creek; Confinement: unconfined; Fish Species present: CH, WS, FC, SC |
| SF Toutle 20 | Description: Disappointment Creek to end of anadromous distribution; Confinement: confined; Fish Species present: WS, SC |
| SF Toutle 3 | Description: Johnson Creek to Brownell Creek; Confinement: unconfined to moderate; Fish Species present: WS, FC, SC |
| SF Toutle 4 | Description: Brownell Creek to Thirteen Creek; Confinement: moderate to confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 5 | Description: Thirteen Creek to Eighteen Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 6 | Description: Eighteen Creek to Twenty Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 7 | Description: Twenty Creek to Big Wolf Creek; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 8 | Description: Big Wolf Creek to unnamed LB trib5; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| SF Toutle 9 | Description: unnamed LB trib5 to unnamed LB trib6; Confinement: confined; Fish Species present: WS, FC presumed, SC |
| Shultz Cr trib | Description: mouth to road crossing; Confinement: confined; Fish Species present: WS presumed |
| Shultz Creek 1 | Description: mouth to LB trib at quarry; Confinement: unconfined to moderate; Fish Species present: WS presumed |
| Shultz Creek 2 | Description: LB trib at quarry to RM 2.5; Confinement: confined; Fish Species present: WS presumed |
| Silver Lake 1 | Description: Silver Lake from Hemlock outlet to Hemlock inlet; Confinement: unconfined; Fish Species present: WS, FC presumed |
| Silver Lake 2 | Description: Silver Lake to Sucker Creek; Confinement: unconfined; Fish Species present: WS presumed, FC presumed |

| | **Appendix C: EDT reaches and descriptions** |
|---|---|
| Stankey Cr | Description: mouth to nearly all available habitat; Confinement: moderate to confined; Fish Species present: WS—1.7miles known, 3 miles potential, 0.3 miles presumed |
| Studebaker Cr 1 | Description: mouth to unnamed RB trib 10; Confinement: unconfined to moderate; Fish Species present: FC 2 miles |
| Studebaker Cr 2 | Description: unnamed RB trib10 to Fork; Confinement: unconfined; Fish Species present: WS—0.5 known, 0.3 presumed, 1.2 potential |
| Sucker Cr | Description: Silver Lake to fork to 1 mile up right fork, 1.5 mile up left fork; Confinement: confined; Fish Species present: WS Presumed, FC presumed for 1 mile |
| Thirteen Creek | Description: mouth to fork; Confinement: moderate to confined; Fish Species present: WS |
| Toutle 1 | Description: mouth to unnamed LB trib1; Confinement: unconfined to moderate; Fish Species present: CH, WS, FC, SC |
| Toutle 2 | Description: unnamed LB trib1 to unnamed LB trib2; Confinement: moderate to confined; Fish Species present: CH, WS, FC, SC |
| Toutle 3 | Description: unnamed LB trib to Stankey Creek; Confinement: moderate confinement; Fish Species present: CH, WS, FC, SC |
| Toutle 4 | Description: Stankey Creek to unnamed LB trib3; Confinement: moderate; Fish Species present: CH, WS, FC, SC |
| Toutle 5 | Description: LB trib3 to Rock Creek; Confinement: moderate to confined; Fish Species present: CH, WS, FC, SC |
| Toutle 6 | Description: head of gorge to unnamed LB trib4; Confinement: moderate; Fish Species present: CH, WS, FC, SC |
| Toutle 7 | Description: unnamed LB trib4 to unnamed RB trib1; Confinement: moderate; Fish Species present: CH, WS, FC, SC |
| Toutle 8 | Description: unnamed RB trib1 to Hemlock Creek; Confinement: moderate; Fish Species present: CH, WS, FC, SC |
| Toutle 9 | Description: Hemlock Creek to Fork; Confinement: unconfined; Fish Species present: CH, WS, FC, SC |
| Tradedollar Creek | Description: mouth to increased gradient; Confinement: moderate to confined; Fish Species present: WS presumed |
| Trouble Creek | Description: mouth to RM 3.3; Confinement: confined; Fish Species present: WS presumed |
| Twenty Creek | Description: mouth to RM 0.3; Confinement: confined; Fish Species present: WS |
| unnamed Lake trib | Description: Silver Lake to end of available habitat; Confinement: confined; Fish Species present: WS presumed, FC presumed |
| Whitten Creek | Description: mouth to RM 0.3; Confinement: confined; Fish Species present: WS presumed |
| Wyant Cr 1 | Description: mouth to unnamed LB trib10; Confinement: unconfined to moderate; Fish Species present: WS, FC to RM 1.7 |
| Wyant Cr 2 | Description: LB trib10 to fork at RM 5; Confinement: moderate to confined; Fish Species present: WS—1.0 known, 1.5 potential |

# E.5. Wind River

## E.5.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for the Wind River. In this project we rated over 60 reaches with 46 environmental attributes per reach for current conditions and another 46 for historical conditions. Over 2,700 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data. However, data is available from Gobar Creek (Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.5.2. Recommendations

1. Adult chum salmon, Chinook salmon, and steelhead population estimates should continue. However, more emphasis should be placed on determining the number of hatchery and wild spawners and the reproductive success of hatchery spawners. Summer steelhead and spring Chinook estimates are based on mark-recapture and are considered accurate and precise. Fall Chinook estimates and chum salmon estimates are based on an assumed observer efficiency and are likely to be less reliable. Winter steelhead and coho salmon counts are periodic and not population estimates. Spring Chinook and summer steelhead escapement estimates should be continued and funding secured to develop accurate and precise adult estimates. Smolt population estimates are made for steelhead and spring Chinook, for the entire basin and key watersheds, using mark-recapture. It is not possible to estimate fall Chinook or chum juvenile production since no suitable trapping sites exist lower in the basin and the trap cannot be moved downstream. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective.

2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.

3. Empirical sediment data was only available for a few reaches and derived estimates were used for most of the basin. A sediment monitoring program should be developed to assess the

percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.

4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Flow monitoring in the mainstem Wind River has been inconsistent since the gauge was re-installed. The reliability of this monitoring should be improved. Bed Scour estimates were not available for this basin and bed scour data should be collected and related to peak flows. Re-installation of gauges in Trout, Panther, and Upper Wind should be considered along with the bed scour monitoring.
6. USFS and USGS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey only a lower, and middle mainstem reach and one section of the Little Wind River. In addition, glides and pools were distinguished subjectively and not quantitatively. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. A combination of Ecology and OSU estimates of the Benthic Index of Biological Integrity (B-IBI) were used to develop EDT ratings. These data were clustered above the CNFH and in Trout Creek. They should be expanded to other basins
8. Obstructions were not rated and passage was assumed to be 100%. These ratings should be updated using the SSHIAP database.

## E.5.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This watershed originates from McClellan Meadows, and the maximum elevation is approximately 3,000 ft. The upper elevations are consistent with a rain-on-snow hydrologic regime and the lower elevations are consistent with a rainfall-dominated watershed. The Little Wind River was rated as rainfall dominated for the historic and current conditions. All other watersheds were rated as rain-on-snow (USFS 1996) except Tyee springs and Cold Creek, which had groundwater run-off patterns. These runoff patterns were used to shape estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

#### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—These watersheds do not have artificial flow regulation. These watersheds were given an EDT rating of 0 for the historical and current conditions except for the lowest two reaches of the mainstem Wind River, which are inundated by the Bonneville pool. These reaches were rated as 1.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established except for the lowest reaches of the Wind which are inundated by the Bonneville pool. There is more uncertainty for this rating because water retention time in these reaches has not been measured.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. From 1935 to 1957 annual timber harvest in the Wind River Ranger District was low and consistent (USFS 1996). In the late 1950's harvest increased dramatically. The change in Q2yr, calculated using EDT methodology, from 1935-57 to 1958-79 was 12% (Figure E7-4). For watersheds in which the two-year peak flow increases 12% the EDT rating is 2.3, and this was used for the mainstem Wind River. Direct measures of inter-annual high flow variation are not available for most subwatersheds in the Wind River. USFS has conducted watershed analysis in the Wind River (USFS 1996). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-36. USFS estimates were used for subwatersheds.

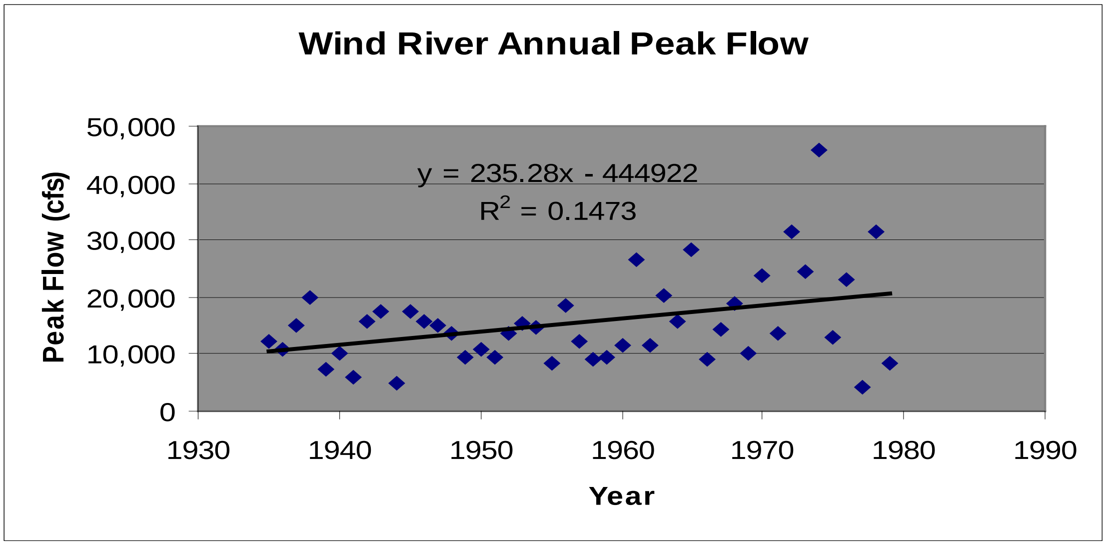


**Figure E7-4.** **Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

**Table E7-36. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. A combination of empirical information (mainstem Wind River) and derived information (remainder of the basin) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive (Spencer et al. 1996). Therefore, we rated the template and current conditions the same (EDT rating of 2).

However, water withdrawals may reduce summer flow. USFWS has water rights for the operation of Carson National Fish Hatchery (CNFH) from the mainstem Wind River and Tyee Springs. USFS has water rights for the former nursery on Trout Creek, although they are not currently used. Water withdrawals are variable for the hatchery depending on the amount of water available from Tyee springs and fish production needs. Recently, USFWS has tried to minimize mainstem Wind River withdrawals. In Trout Creek, the USFS has closed the nursery. No change in low flow was used in this modeling effort, but if irrigation is resumed in Trout Creek or if the hatchery water withdrawals increase, this attribute should be adjusted accordingly.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff and hydroelectric development in this subbasin. There are no major metropolitan areas in these watersheds with large areas of impervious surfaces. The lowest two mainstem reaches have diel variation caused by the operation of Bonneville Dam and were rated accordingly.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watersheds. Based on change in Q2yr from the USGS gauge, we estimated a 12% increase in peak high flows in the lower mainstem, with other subbasins ranging from 0% to 14%. Since there was no data for this attribute, it was suggested that its rating should be the same as the changes in inter-annual variability in high flows (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification or water withdrawal was located within the reach. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). USFS and USGS surveyed widths as part of habitat surveys from the late 1980’s to the present (Pat Connoly -USGS and Brian Bair-USFS unpublished data). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement.

*Level of Proof*—A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof ranged from thoroughly established in reaches with direct observations to a strong weight of evidence in support but not fully conclusive in reaches were expanded information was used. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual “wetted width-high” values in reaches where data was available, and a 1.6 multiplier (60%) to expand “wetted width-low” values for reaches without high flow data. In canyon areas, summer flows were expanded by 20-40% depending of reach characteristics.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as percentage gradient) was calculated by dividing the change in reach elevation by the reach length. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

## Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed for confinement ratings (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings (Table E7-37).

**Table E7-37. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and Limiting Factors Analysis (LFA) to estimate EDT ratings. Ratings were categorical due to the lack of field surveys to corroborate GIS, map, and photo estimates.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.

*Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter). Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower reaches inundated by the construction of Bonneville Dam were rated as glides and pools depending on the amount of inundation.

WDFW and USFS habitat surveys in 2002 followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore it was estimated but not surveyed by WDFW. USGS used modified USFS stream survey level 2 protocols, and delineated glide habitat.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (DNR 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to

15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we assumed pool habitats were in the "good" range and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. An EDT rating of 0 was assigned to Aa+ and A channels, a rating of 0 to 1 for B channels, while low gradient C channels were assigned EDT ratings of 1 to 2 for the current rating and 2 to 3 for the historical rating. Off-channel habitat is not significant in the Wind River, with the exception of the inundated reach. Old photographs suggested that substantial off-channel habitat was historically present.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for any barriers except Hemlock Dam. In most cases known fish distribution stopped at all barriers. In some cases, where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. Most watersheds in this unit are forested with limited agriculture and residential use. Water withdrawals were assumed to be minimal in most areas. Reaches with low gradient, unconfined areas (i.e. farmland) and/or reaches with dwellings built next to the stream were given an EDT rating of 0 to 1 to account for occasional withdrawals. All other reaches were rated at 0. Known water withdrawals occur at Carson National Fish Hatchery and Hemlock Dam. Data was reviewed to develop ratings for these reaches.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table is based on professional judgment and relates bed scour to confinement, wetted width (high flow), and gradient. It assumes bed scour increases as gradient, wetted width, and confinement increase. For low gradient slough like reaches, we reduced the bed scour rating to ~1, since these reaches are unconfined and influenced by the Columbia River.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as peak flow and hydro-confinement increased. For example, if in the template condition a reach had a peak flow of 2.0 and in the current condition peak flow increased to 2.3, while hydro-confinement ratings increased from 0 to 1, we assumed a 0.05 increase in bed scour for every 0.1 increase in peak flow and a 0.1 increase for every 1.0 increase in hydro-confinement. In this example the bed scour increased by 0.25

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—In watersheds that are rainfall dominated anchor ice and icing events do not occur. For elevations less than 1000 ft., EDT ratings of 0 were assigned to all reaches in the historical and current condition. For those from 1,000 to 2000 ft. EDT ratings of 1 were assigned. This was based on personal winter observation in the Wind River and discussions with CNFH staff.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 0.0 -1.0 depending on the density of large trees and bank stability. Riparian zones with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—Wood density was estimated during USFS and WDFW habitat surveys where density of wood equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. Due to their confinement, it was believed during high flows these reaches did not retain wood as well as other sections. When survey data was not available, wood densities were extrapolated from reaches with data. EDT Rating based on TFW standard of all wood. USFS surveys measured large wood or key pieces. Key pieces were converted to wood based on surveys comparison of Key pieces to total wood that indicate key pieces ~35% of all wood. If wood in a reach was unknown, a rating from adjacent reach was used or the subbasin average of 2 was used.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) found that as road density increased by 1 $mi/mi^2$, fine sediment levels increased by 2.65%. However, Duncan and Ward (1985) found a lower increase in the percentage of fines in southwest Washington, but attributed much of the variation in fines to different geology. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 $mi/mi^2$ of roads for all watershed ($R^2 = 0.31$, n=17). The increase was 1.52% per 1 $mi/mi^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored was excluded. Rather than use all three years of Layout Creek data , only the median was used and the final relationship used for EDT was 1.34% increase in fines per1 $mi/mi^2$ ($R^2$=0.56, n=15) (Figure E7-5).

Tidal reaches with lower gradients were given an EDT rating of 4. Slough-like reaches above tidal reaches or tidal reaches with increased flow during outgoing tide (i.e. Germany Ck.) were rated as follows: rating from road density scale + 1.

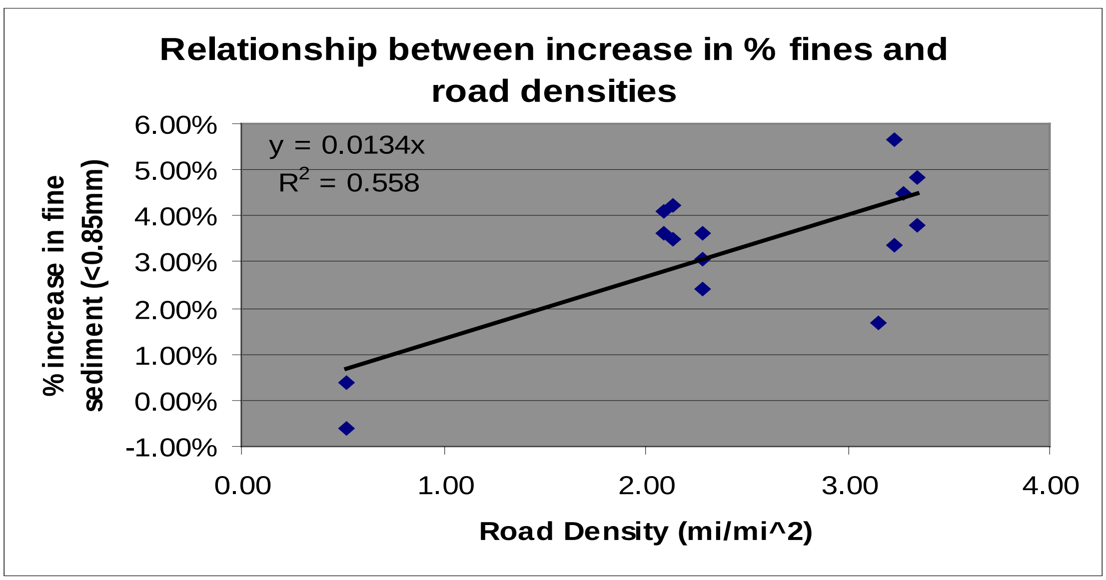


**Figure E7-5. Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), we assumed this level was the same for embeddedness, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

We assumed that the percent embeddedness was directly related to percentage of fines in spawning gravel. We used the Wind River data mentioned above to develop a scale relating road density to percent embeddedness. Tidal reaches with lower gradients were given an EDT rating of 3. Slough-like reaches above tidal reaches or tidal reaches with increased flow during outgoing tide (i.e. Germany Ck.) were rated as follows: rating from road density scale + 1.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process that occasionally increases turbidity after an extensive hot burn. Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture.

Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels to be an EDT rating of 0 in small tributaries, 0.3 in medium tributaries, and 0.5 in the mainstem.

Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout, Panther, and Middle Wind are over 40 mg/L, and other basins are 5-40mg/L, with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L level lasts 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for the lower mainstem.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Temperature loggers have been extensively placed in the Wind River subbasin by USFS, UCD, USGS, and USFWS. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern "TmpMonMax Rainfall", TmpMonMax Groundwater", and TmpMonMax Transitional" for the rainfall, groundwater and rain-on-snow-transitional watersheds, respectively.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream. Pelletier (2002) estimated current maximum temperatures in the Wind River temperature TMDL and this information was also used to fill in missing data.

Historical temperatures are unknown the in the Wind River subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—Derived information was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) – 5.8305 ( $R^2$= 0.32, n=27). This was used to generate categorical ratings (Table E7-38) based on elevation. For the Wind, we used actual data, where available, to develop non-categorical ratings. It should be noted that reaches with lakes/wetlands (Falls and EF Trout) and immediate downstream reaches have colder minimum temperatures (higher EDT ratings) and those with strong groundwater influence (Upper Trout) have warmer minimum temperatures (lower EDT ratings).

**Table E7-38. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

The historic minimum temperature was assumed to be the same as current minimum temperatures except for the Hemlock Dam reach which is 0.3 (EDT rating) lower than current. There is some support that historical minimum temperatures were warmer due to more mature forest stands, but we did not use this information due to the limited support and the fact that fire disturbance regimes in these forests would have periodically led to these conditions naturally.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established in the Wind. Expansion of empirical ratings was used for the remainder of the Wind and other basins.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Wind, Lower Washougal, Middle Washougal, NF Lewis, EF Lewis, Cedar, Kalama, Elochoman, and Grays Rivers using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. We used the mean July to September flow to determine the mean alkalinity values. For basins without flow data, we used mean summer alkalinity values. Alkalinity values were 22, 15, 12, 16, 20, 27, 21, 27, and 30 mg/L, respectively. Additional data was available on the Wind River for reach specific ratings from UCD and USFS water quality sampling. For other basins, the standard basin alkalinity value was used. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—Derived information was used to estimate this attribute from conductivity measurements. Since alkalinity is did not vary much between adjacent basins and is believed to be relatively constant within a basin, estimated values were expanded for all reaches within a basin. Expert opinion was used to estimate the historical ratings for this attribute since historical data was lacking. The level of proof for the current condition is thoroughly established, generally accepted and good peer-reviewed empirical evidence in favor. For the historical data there is has a strong weight of evidence but not fully conclusive due to lack of data.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. Historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) and Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All reaches in these watersheds were assumed to be unimpaired for dissolved oxygen. These are representative of free flowing reaches. The lower slough reaches in Hamilton, Hardy, EF Lewis, Kalama, and Coweeman are likely to have increased temperatures and lower DO levels in July/August.

*Level of Proof*—Empirical information and expert opinion were used to estimate the current and historical ratings for this attribute. Available current data support no problems with dissolved oxygen in flowing reaches. The level of proof for the current condition is thoroughly established, generally accepted and has good peer-reviewed empirical evidence in favor. In slough reaches, where no data was available, derived information and expert opinion was used. For the slough reaches and historical data there is has a strong weight of evidence but not fully conclusive due to lack of data. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off.

Nutrient enrichment throughout these watersheds was assumed to be non-existent or at low levels. Fertilizing by timber companies may have some minimal effect but it is likely that changes in nutrient levels from normal forest activities is near zero (WFPB 1997)

Potential low levels of nutrients from Carson NFH enter in the top of Wind 5c. Potential nutrient sources exist from septic tanks at Trapper Creek (cabins), Wind 5c (Canavina Rd), Wind 5a (homes above Stabler), and Panther 1b (homes and cabins). The mainstem Wind River from CNFH to the mouth of Trout Creek was rated as 1 due to hatchery and homes with septic tanks. The ratings were reduced to 0.5 below Trout, and to 0 below Panther. Septic at other sites was assumed to be negligible based on low fecal coliform samples and was rated at 0. If the Wind River nursery is re-opened water quality sampling for nutrients below this site is recommended.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Lower Wind, Upper Wind, Panther Creek, and Trout Creek (pers. com. Cochran, WDFW), (2) electro-shocking in 2002 by USFS and USGS in Upper Wind, Panther, and Trout & tributaries (pers. com. Connoly USGS, and Bair USFS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW snorkel surveys on the Wind and Panther (pers. com. Cochran, WDFW), (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967).

Historic reaches below Shipherd Fall contained chum salmon, steelhead, Chinook salmon, coho salmon, sea-run cutthroat, bridgelip sucker, largescale sucker, prickley sculpin, and shorthead sculpin. Historic reaches above Shipherd Falls-include shorthead sculpin, whitefish, steelhead/rainbow; and spring Chinook should be added for current distribution. Whitefish have not been observed above Dry Creek. Sculpins are not found in Trout Creek above Hemlock. Current species in reach 1 (inundated) include the 29 from the Columbia. In Reach 2, the current list includes the historic species plus stickleback. Brook trout are found presently found in upper Trout Creek and its tributaries. Lamprey, while present in the basin, are not included in the species count (Larry Lestelle pers com)

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Sloughs likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coastrange , reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW). The majority of these species were dropped out at Wind 2.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

Brook and cutthroat trout plants have been extensive in the Wind River basin but have been discontinued for decades. However, naturally reproducing brook trout are presently found in upper Trout Creek and its tributaries based on smolt trap (WDFW) and electroshock (USFS & USGS) data.

Spring Chinook salmon were introduced and are currently found below Wind 6b. Bright fall Chinook salmon are found through Reach 3. The inundated reach (Wind 1) has potential for more exotics from the Columbia River, as many as 12 species from the Columbia River may migrate up to Reach 1. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. The majority of these species were dropped out at Wind 2. At the Lower Wind River Smolt trap the catch has included suckers, whitefish, peamouth, shiners sticklebacks, dace, sculpins, and lamprey (Charlie Cochran, pers Com)

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW).

CNFH releases 1.6 million spring Chinook smolts from reach Wind 5C. Spawners use up to reach 6b annually. The hatchery steelhead program (20-40,000 annual release) was discontinued in 1997 and hatchery trout releases in Hemlock lake discontinued in 1994. Adult snorkel surveys indicate hatchery steelhead distributions were found in the same reaches as wild steelhead (snorkel survey memos). Therefore we assumed distribution was the same as wild fish. However, hatchery steelhead have not been passed above the Trout Creek Trap since 1992 except when not operated in the middle 1990's and part of 1999. Hatchery outplants in tributaries and in the mainstem Wind River above Ninemile Creek were reduced to zero, since steelhead releases are discontinued and there was little evidence of straying.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. CNFH operates in Wind 5C, but hatchery Chinook spawn through reach 6B. The reaches from Wind 1 to 6B are rated as 3. Hatchery steelhead plants were discontinued in 1997 and hatchery trout plants in Hemlock Lake were discontinued in 1994. All other reaches were assumed to have impacts from hatchery steelhead and were rated as 1. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use (Wind below Shipherd Falls and Hemlock Lake); a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use (Upper Middle Wind or Flats due to Beaver Camp, and intense Spring Chinook Fishery); 2 was given to reaches with multiple access points (Lower Middle Wind, Wind Canyon due to Spring Chinook fishery and kayaking, near campgrounds on Wind and Panther, and trailheads) through public lands or unrestricted access through private lands; 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands (most tributaries with limited access); 0 was given to reaches with no roads and that are far from population centers (Headwaters Wind, and tributaries with difficult access).

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species is unknown in these watersheds.

We assumed current predation is similar to template conditions except for the lowest reach (Wind 1), which was given a rating of 4 due to reach inundation by the Bonneville Pool and an increase in Columbia River predatory fishes. We assumed there is an increase in predation at Hemlock Lake due to ducks, birds, and otters. This reach was rated at 3.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches).

Historic fall Chinook and chum spawned from the mouth to Little Wind River and carcasses were very abundant; from Little Wind to Shipherd Falls, due to coho, Chinook, and some chum, carcasses were very abundant (See USFWS hatchery fall Chinook records); Little Wind had coho and winter steelhead and was rated as moderately abundant; and reaches above Shipherd Falls had only steelhead and carcasses were not abundant. Currently spring Chinook spawn between Beaver Camp to Ninemile ~300 annually (WDFW escapement database). Approximately 600 Tule and Bright fall Chinook spawn between the boat ramp and mouth of Little Wind (WDFW escapement database).

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. Slightly disturbed Rosgen B Channels in the Cowlitz and Grays had ratings of 0.1 to 1.4, but were very close to the averaged undisturbed rating of 0.6. Therefore, for current Rosgen B-channels we assumed the same rating as historic. For disturbed Rosgen C-channels in the Wind River the EDT benthos rating decreased to 1.5. Disturbed C-channels are likely to be more impacted by human activities due to their character than B-channels and the 1.5 EDT rating was used to describe current C-channels. Lower Cedar Creek has a rating B-IBI score of 26 or EDT score of 2.6. This reach is right below a disturbed C-Channel where the riparian encroachment has reduced shade, increased temperature, and nutrient levels (fecal coliform) have increased due to agriculture or septic tanks leaks. Middle to upper portions of Salmon Creek had similar B-IBI scores. Lower Salmon Creek, which is considered to have the most degraded water quality reaches in the LCR, had B-IBI scores that were less than 23. Cedar and Salmon Creek benthos score are not considered typical for most of southwest Washington.

**Acknowledgements**

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Ecology, UCD, USFS, USGS, and OSU for providing their survey data, especially Brian Bair (USFS), Pat Connolly (USGS), and Shannon Claeson (OSU). We thank the staff at Mobrand Biometric Inc for assistance with the EDT model especially Kevin Malone, Jennifer Garrow, Greg Blair, and Rick Paquette.

# E.6. Grays River

## E.6.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for the Grays River. In this project we rated 85 reaches with 45 environmental attributes per reach for current conditions and another 45 for historical conditions. Over 7,650 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data. However, data is available from Gobar Creek (Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.6.2. Recommendations

1. Adult chum, steelhead, and Chinook salmon population estimates should continue. However, more emphasis should be placed on determining the number of hatchery fish and their reproductive success. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective. Juvenile programs should be initiated and adult programs should be maintained and improved as needed.
2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.
3. Empirical sediment data was only available for a few reaches and derived estimates were used for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.
4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Bed Scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. Conservation district habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey a few representative reaches. To accurately estimate stream

habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.

7. Macro invertebrate sampling was not available. A combination of Ecology and OSU estimates of the Benthic Index of Biological Integrity (B-IBI) from the Wind River were used to develop EDT ratings in theWashougal Basin.
8. Obstructions were not rated and passage was assumed to be 100%. These ratings should be updated using the SSHIAP database.

## E.6.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This maximum elevation in these watershed is approximately 2,000 ft. These upper elevations are consistent with a rainfall-dominated watershed. These subbasins were rated as rainfall dominated for the historic and current conditions. Groundwater influences are present in the Crazy Johnson and Gorley Creeks. These runoff patterns were used to shape estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watersheds, which did not have artificial flow regulation was given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Direct measures of inter-annual high flow variation are not available for this subbasin. Sufficient data was not available to conduct a Q2yr analysis in the Grays River . USFS estimates support a slight peak flow increases for subbasins in Southwest Washington (Table E7-39). Calculated Q2yr changes are Wind (13%), Washougal (17%), Kalama (17%), and Toutle (31%) after Mt St Helens and intensive logging. We used Naselle as a surrogate for Grays because of the basins similar climate and soils. The estimate increase in peak flow was and EDT rating of 2.4 (Mobrand 2002). Exceptions were Gorley and Crazy Johnson, which are groundwater streams, which did not have increase in peak flow. SF Grays River and Hull Creek had road densities that were less (~4 mi/sq mi) so reduced peak flow to 2.3

**Table E7-39. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10 -12% |
| Rock Cr | | 1 -5% |
| Upper Kalama | | 5 - >10% |
| Cispus | | <10% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive (Spencer et al. 1996). Therefore, we rated the template and current conditions the same (EDT rating of 2).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff for most of the basin. This attribute is influenced by the % impervious surfaces. Most reaches are influenced by forestry and impervious surfaces are low. We had no information on impervious surfaces but if information becomes available this attribute should be adjusted.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the remaining current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watersheds. USFS (1996) indicated peak flow may have increased by 13% in some subwatersheds. Since there was no data for this attribute, it was suggested that its rating should be the same as the changes in inter-annual variability in high flows (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification or water withdrawal was located within the reach. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement.

*Level of Proof*—A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof ranged from thoroughly established in reaches with direct observations to a strong weight of evidence in support but not fully conclusive in reaches were expanded information was used. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual "wetted width-high" values in reaches where data was available, and a 1.6 multiplier (60%) to expand "wetted width-low" values for reaches without high flow data. In canyon areas, summer flows were expanded by 20-40% depending of reach characteristics.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as percentage gradient) was calculated by dividing the change in reach elevation by the reach length. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed for confinement ratings (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings (Table E7-40).

**Table E7-40. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and Limiting Factors Analysis (LFA) to estimate EDT ratings. Ratings were categorical due to the lack of field surveys to corroborate GIS, map, and photo estimates.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.

*Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter). Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower reaches inundated by the construction of Bonneville Dam were rated as glides and pools depending on the amount of inundation.

WDFW habitat surveys followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore it was estimated but not surveyed by WDFW.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (WFPB 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we assumed pool habitats were in the "good" range and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. These low gradient C channels were assigned up to a 15% off-channel habitat factor, historically and 0% currently. Off-channel habitat is not significant except in the lower reaches. These reaches were assigned an EDT rating of up to 10% historic off-channel habitat factor due to the backwater of the Columbia River and assumed beaver populations. Old photographs suggested that substantial off-channel habitat was historically present.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. In most cases, known fish distribution stopped at all barriers. In some cases, where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition.  Most watersheds in this unit are forested with residential use in the lower portion of the subbasin.  Water withdrawals occur at the WDFW Hatchery on the WF Grays River and at the Alder Creek ponds in the upper basin. These reaches were rated at a 2.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.  For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins.  Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW).  This table was modified to incorporate the new EDT revisions for bed scour ratings.  The table is based on professional judgment and relates bed scour to confinement, wetted width (high flow), and gradient.  It assumes bed scour increases as gradient, wetted width, and confinement increase.  For low gradient slough like reaches, we reduced the bed scour rating to ~1, since these reaches are unconfined and influenced by the Columbia River.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as peak flow and hydro-confinement increased. For example, if in the template condition a reach had a peak flow of 2.0 and in the current condition peak flow increased to 2.3, while hydro-confinement ratings increased from 0 to 1, we assumed a 0.05 increase in bed scour for every 0.1 increase in peak flow and a 0.1 increase for every 1.0 increase in hydro-confinement.  In this example the bed scour increased by 0.25.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—In watersheds that are rainfall dominated anchor ice and icing events do not occur.  For elevations less than 1000 ft., EDT ratings of 0 were assigned to all reaches in the historical and current condition.  For those from 1,000 to 2000 ft. EDT ratings of 1 were assigned.  This was based on personal winter observation in the Wind River and discussions with CNFH staff.  Based on elevation the same icing ratings were used in the Grays River.

*Level of Proof*—Empirical observations were used to establish an elevation /icing relationship and this derived information was used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 0.0 -1.0 depending on the density of large trees and bank stability. Riparian zones with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating.

Riparian in upper mainstem and tributary reaches (above HWY 14) is considered in good condition, which corresponds to an EDT rating of 1. Below the mouth of the WF Grays riparian function is degraded due to forest clearing and diking. Ratings in these reaches are between two and three.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—Wood density was estimated during USFS and WDFW habitat surveys where density of wood equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. Due to their confinement, it was believed during high flows these reaches did not retain wood as well as other sections. When survey data was not available, wood densities were extrapolated from reaches with data. EDT Rating based on TFW standard of all wood. Conservation district surveys did not appear to follow the TFW protocol and adjustments were made to these surveys based on WDFW habitat surveys. The final rating suggest a significant loss of wood has occurred in this subbasin.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) found that as road density increased by 1 mi/mi$^2$, fine sediment levels increased by 2.65%. However, Duncan and Ward (1985) found a lower increase in the percentage of fines in southwest Washington, but attributed much of the variation in fines to different geology. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 mi/mi$^2$ of roads for all watershed ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 mi/mi$^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored was excluded. Rather than use all three years of Layout Creek data , only the median was used and the final relationship used for EDT was 1.34% increase in fines per1 mi/mi$^2$ ($R^2$=0.56, n=15) (Figure E7-6). Road densities were obtained from URS (2003) report to the LCFRB and these were incorporated into the Wind River relationship to estimate fines. Tidal reaches with lower gradients were rated one point higher.

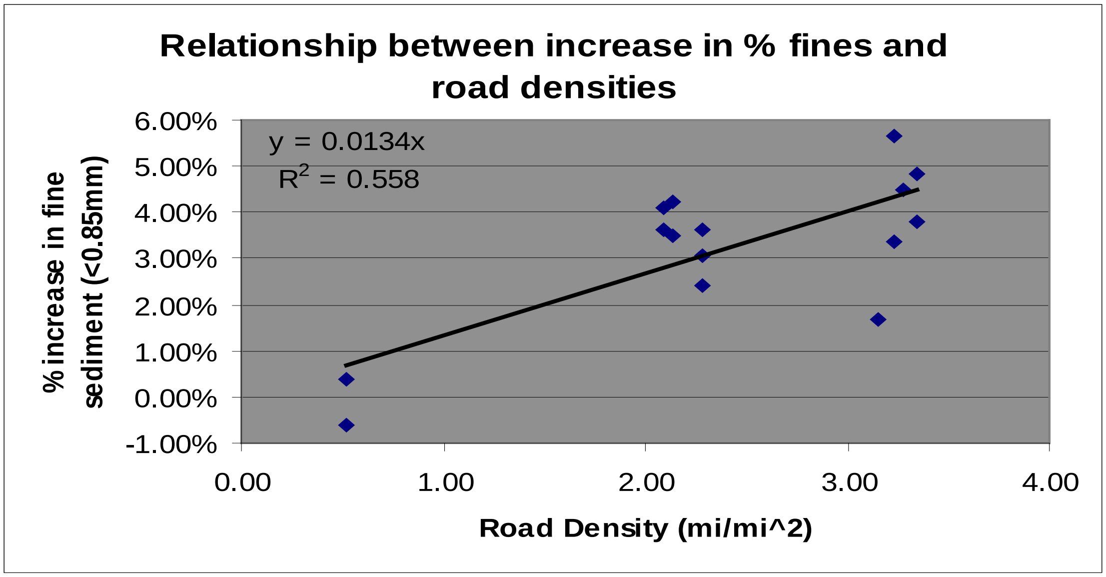


**Figure E7- 6. Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), we assumed this level was the same for embeddedness, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

We assumed that the percent embeddedness was directly related to percentage of fines in spawning gravel. We used the Wind River data mentioned above to develop a scale relating road density to percent embeddedness and applied this to the Grays River. Tidal reaches with lower gradients were rated one point higher.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: SEV = a + b(lnX) + c(lnY) , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process, that occasionally increases turbidity after an extensive hot burn. Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels to be an EDT rating of 0 in small tributaries, 0.3 in medium tributaries, and 0.5 in the mainstem.

Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the rivers from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout, Panther, and Middle Wind are over 40 mg/L, and other basins are 5-40mg/L, with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L level lasts 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for the lower mainstem. These ratings were applied to the Grays River.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Temperature loggers have been extensively placed in the Grays subbasin by the conservation district and WDFW. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern "TmpMonMax Rainfall", TmpMonMax Groundwater", and TmpMonMax Transitional" for the rainfall, groundwater and rain-on-snow-transitional watersheds, respectively.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

Historical temperatures are unknown the in this subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—Derived information was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) – 5.8305 ( $R^2$= 0.32, n=27). This was used to generate categorical ratings (Table E7-41) based on elevation. For the Wind, we used actual data, where available, to develop non-categorical ratings. It should be noted that reaches with lakes/wetlands (Falls and EF Trout) and immediate downstream reaches have colder minimum temperatures (higher EDT ratings) and those with strong groundwater influence (Upper Trout) have warmer minimum temperatures (lower EDT ratings). The Wind River ratings were applied to the Grays River.

**Table E7-41. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

The historic minimum temperature was assumed to be the same as current minimum temperatures. There is some support that historical minimum temperatures were warmer due to more mature forest stands, but we did not use this information due to the limited support and the fact that fire disturbance regimes in these forests would have periodically led to these conditions naturally.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established in the Wind. Expansion of empirical ratings was used for the remainder of the Wind and other basins.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Wind, Lower Washougal, Middle Washougal, NF Lewis, EF Lewis, Cedar, Kalama, Elochoman, and Grays Rivers using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. We used the mean July to September flow to determine the mean alkalinity values. For basins without flow data, we used mean summer alkalinity values. Alkalinity values were 22, 15, 12, 16, 20, 27, 21, 27, and 30 mg/L, respectively. The Grays River alkalinity data was used for this subbasin. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—Derived information was used to estimate this attribute from conductivity measurements. Since alkalinity is did not vary much between adjacent basins and is believed to be relatively constant within a basin, estimated values were expanded for all reaches within a basin. Expert opinion was used to estimate the historical ratings for this attribute since historical data was lacking. The level of proof for the current condition is thoroughly established, generally accepted and good peer-reviewed empirical evidence in favor. For the historical data there is has a strong weight of evidence but not fully conclusive due to lack of data.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. No data was available for this subbasin. Historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) and WDFW hatchery data found that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All riverine reaches in these watersheds were assumed to be unimpaired for dissolved oxygen. Coweeman sampling indicated DO levels could drop below 8 mg/L in slough like reaches. This information was used to rate the lower sloughs of the Grays River.

*Level of Proof*—Empirical information and expert opinion were used to estimate the current and historical ratings for this attribute. Available current data support no problems with dissolved oxygen in flowing reaches. The level of proof for the current condition is thoroughly established, generally accepted and has good peer-reviewed empirical evidence in favor. In slough reaches, where no data was available, derived information and expert opinion was used. For the slough reaches and historical data there is has a strong weight of evidence but not fully conclusive due to lack of data. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the “pristine” state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off. The potential for an increase in nutrients from septic tanks and agriculture in the lower river is possible, and so is an increase from hatchery operations in the West Fork Grays River. These reaches were rated as 1. Assumed all other reaches are similar to historic levels.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Lower Wind, Upper Wind, Panther Creek, and Trout Creek (pers. com. Cochran, WDFW), (2) electro-shocking in 2002 by USFS and USGS in Upper Wind, Panther, and Trout & tributaries (pers. com. Connoly USGS, and Bair USFS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW snorkel surveys on the Wind and Panther (pers. com. Cochran, WDFW), (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). Lamprey, while present in the basin, are not included in the species count (Larry Lestelle pers com).

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Sloughs likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coastrange , reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW).

Fish community richness has increased due to species introductions. These are warmwater and coolwater fishes from the Columbia River, which migrate through the lower Grays River.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

The tidal reaches have potential for use by exotic fishes from the Columbia River, as many as 12 species from the Columbia River may migrate into these reaches. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. Species introductions are due to warmwater fishes in the lower reaches of the Grays River. Lowest reaches were rated 3 based on derived info from other basins. Ratings were reduced above this site based on professional opinion, and WDFW electroshocking data. Blasting falls above in mainstem above WF Grays River allowed coho access. Chinook salmon have difficulty accessing this area. These areas rated as a 1. Tidal and estuary reaches rated 2 through 4 due to introduced fishes from the Columbia River. Grays 2 rated at 1 due to some introduced Columbia River fish migrating into this reach.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW). Current hatchery operates on the WF Grays River; this and downstream reaches were rated at 4. The discontinued hatchery program at Weyco Ponds near Alder Cr was the basis for EDT ratings of 2 in mainstem Grays River above the West Fork Grays River . Both these programs were rated as 3.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency. Stocking in the WF Grays River and at the Alder Creek ponds was the basis for the ratings for this attribute. All other reaches were as rated as a zero.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use ; a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; 2 was given to reaches with multiple access points through public lands or unrestricted access through private lands; 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands; 0 was given to reaches with no roads and that are far from population centers. Accept in the lower basin, much of the access is restricted by private timber companies. Due to limited use and access, EDT ratings ranged from 0 to 2.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Predation has increased in reaches connected to Columbia River due to warmwater and coolwater species introductions. Predation risks increased due to introduced fish moving up from the Columbia River. Predation risk has also increased due to yearling hatchery release from the Grays River Hatchery.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches). Chum salmon are the most abundant anadromous salmonid and access reaches up to Highway 14. Current estimates of carcasses were derived from estimates of chum salmon escapement prior to the establishment of a hatchery chum program. Reaches with coho now assumed to be 4 except in reaches near WF Grays River hatchery, where they were increased to 3. Chinook abundance very low in mainstem below WF Grays River and is ~100 adults since the closure of the hatchery. Chum Salmon abundance were very high in Crazy Johnson and Gorley Creeks, which corresponds to an EDT rating of 0.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. Slightly disturbed Rosgen B Channels in the Cowlitz and Grays had ratings of 0.1 to 1.4, but were very close to the averaged undisturbed rating of 0.6. Therefore, for current Rosgen B-channels we assumed the same rating as historic. For disturbed Rosgen C-channels in the Wind River the EDT benthos rating decreased to 1.5. Disturbed C-channels are likely to be more impacted by human activities due to their character than B-channels and the 1.5 EDT rating was used to describe current C-channels. Lower Cedar Creek has a rating B-IBI score of 2.6 or EDT score of 2.6. This reach is right below a disturbed C-Channel where the riparian encroachment has reduced shade, increased temperature, and nutrient levels (fecal coliform) have increased due to agriculture or septic tanks leaks.

B-IBI scores from the Wind River indicate little degradation for Rosgen B channels. Therefore, the 0.6 reference reach rating for current and historical reaches with confined channels. For C channels ratings were degraded to 1.6 based on Wind River data, which supported that B-IBI scores were reduced in less confined channels. Historical less confined channels in the lower basin were rated at 1, current rating was increased to 2 based on nutrients, water temps and DO.

**Acknowledgements**

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Ecology, UCD, USFS, USGS, and OSU for providing their survey data, especially Brian Bair (USFS), Pat Connolly (USGS), and Shannon Claeson (OSU). We thank the staff at Mobrand Biometric Inc for assistance with the EDT model especially Kevin Malone, Jennifer Garrow, Greg Blair, and Rick Paquette.

# E.7. Lewis River

## E.7.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for the Lewis River. In this project we rated 68 reaches with 45 environmental attributes per reach for current conditions and another 465 for historical conditions. Over 2,700 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data. However, data is available from Gobar Creek (Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.7.2. Recommendations

1. Adult chum salmon, Chinook salmon, and steelhead population estimates should continue. However, more emphasis should be placed on determining the number of hatchery and wild spawners and the reproductive success of hatchery spawners. Summer steelhead and spring Chinook estimates are based on mark-recapture and are considered accurate and precise. Winter steelhead, fall Chinook estimates and chum salmon estimates are based on an assumed observer efficiency and are likely to be less reliable. Coho salmon counts are periodic and not population estimates. Summer steelhead escapement estimates should be continued and funding secured to develop accurate and precise adult estimates. Juvenile outmigrant estimates are made annual for Lewis Rievr fall Chinook and all species at Cedar Creek and in 2000 for EF steelhead and coho in the EF Lewis River. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective. These programs should be maintained and improved as needed.
2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.
3. Empirical sediment data was only available for a few reaches and derived estimates were used for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.

4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Gauge stations in Cedar Creek @ Grist Mill, EF Lewis @ Heisson, and Lewis @ Merwin provide flow data. Bed Scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. USFS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey a few representatative reaches. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. Macro invertebrate sampling was available in Cedar Creek. A combination of Ecology and OSU estimates of the Benthic Index of Biological Integrity (B-IBI) from the Wind River were used to develop EDT ratings in the Lewis Basin.
8. Obstructions were not rated and passage was assumed to be 100%. These ratings should be updated using the SSHIAP database.

## E.7.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This maximum elevation in this watershed is approximately 3,000 ft. The upper elevations are consistent with a rain-on-snow hydrologic regime and the lower elevations are consistent with a rainfall-dominated watershed. This subbasin was rated as rainfall dominated for the historic and current conditions except for upper portions on the EF Lewis River above Horseshoe Falls, which were rated as rain-on-snow. These runoff patterns were used to shape estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—The Lewis River below Merwin dam is regulated but no regulation occurs in the remainder of the basin. The watersheds, which did not have artificial flow regulation were given an EDT rating of 0 for the historical and current conditions. Water storage behind the Lewis River dam is in excess of 60 days and Lewis River mainstem reaches below the dam were rated as 4.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Direct measures of inter-annual high flow variation are not available for most subwatersheds in the Lewis River. The Q2yr calculation showed no difference during the period of record for the EF Lewis. However, EF Lewis was recovering from the Yacolt burn when the gage was installed. USFS watershed analysis suggest >10% increase in peak flow. Washougal and Wind showed a 17% and 13% increase in Q2yr. These rating suggest 2.3 to 2.4 rating. We used 2.3 for the EF Lewis above Lucia Falls and 2.4 for the area below Lucia Falls. Cedar Creek was assumed to be 2.3 and Lewis below Merwin 1.0 due to hydro-regulation.

USFS has conducted watershed analysis in the EF Lewis (USFS 1996). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-42. USFS estimates were used for subwatersheds.

**Table E7-42. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| East Fork Lewis | 9 | 5 –13% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive (Spencer et al. 1996). Therefore, we rated the template and current conditions the same (EDT rating of 2). Due to flow regulation below Merwin Dam flow regulation has increased summer low flow. These reaches received an EDT rating of 1. Water withdrawals may occur in the subbasin but these are likely to be for occasional residential use and were not factored into the EDT rating.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff for most of the basin. Reaches influenced by hydroelectric development in this subbasin were rated 3 for an average change of 8 inches in stage per hour.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Empirical information was used to estimate change in gauge height per hour on below Merwin Dam. Derived information was used to estimate the remaining current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watersheds. USFS (1996) indicated peak flow may have increased by 13% in some subwatersheds. Since there was no data for this attribute, it was suggested that its rating should be the same as the changes in inter-annual variability in high flows (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification or water withdrawal was located within the reach. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). USFS surveyed widths as part of habitat surveys from the late 1980's to the present (Darryl Hodges-USFS unpublished data). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement.

*Level of Proof*—A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof ranged from thoroughly established in reaches with direct observations to a strong weight of evidence in support but not fully conclusive in reaches were expanded information was used. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual "wetted width-high" values in reaches where data was available, and a 1.6 multiplier (60%) to expand "wetted width-low" values for reaches without high flow data. In canyon areas, summer flows were expanded by 20-40% depending of reach characteristics.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we

expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as percentage gradient) was calculated by dividing the change in reach elevation by the reach length. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed for confinement ratings (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings (Table E7-43).

**Table E7-43. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and Limiting Factors Analysis (LFA) to estimate EDT ratings. Ratings were categorical due to the lack of field surveys to corroborate GIS, map, and photo estimates. Hydroconfinement primarily occurs in the EF Lewis below Daybreak Park and in the NF Lewis below Woodland due to loss of muti-thread channels into single thread channel in part due to dikes and filling in of side channels

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools*.* *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter). Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower reaches inundated by the construction of Bonneville Dam were rated as glides and pools depending on the amount of inundation.

WDFW, USFWS, and USFS habitat surveys followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore it was estimated but not surveyed by WDFW.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (WFPB 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we assumed pool habitats were in the "good" range and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. These low gradient C channels were assigned up to a 15% off-channel habitat factor, historically and 0% currently. Off-channel habitat is not significant in the EF Lewis River above Lewisville, NF Lewis above Cedar Creek, and upper and lower Cedar Creek. These reaches were assigned an EDT rating of 0 for current and historic off-channel habitat factor. Old photographs suggested that substantial off-channel habitat was historically present.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for any barriers except Merwin Dam. In most cases, known fish distribution stopped at all barriers. In some cases, where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. Most watersheds in this unit are forested with limited agriculture and residential use. Water withdrawals were assumed to be minimal in most areas. Water withdrawals occur at the Lewis River Hatchery and for the Grist Mill fish ladder on Cedar Creek. Other withdrawals for personal use could be occurring on other reaches but since they were not documented, they were ignored.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table is based on professional judgment and relates bed scour to confinement, wetted width (high flow), and gradient. It assumes bed scour increases as gradient, wetted width, and confinement increase. For low gradient slough like reaches, we reduced the bed scour rating to ~1, since these reaches are unconfined and influenced by the Columbia River.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as peak flow and hydro-confinement increased. For example, if in the template condition a reach had a peak flow of 2.0 and in the current condition peak flow increased to 2.3, while hydro-confinement ratings increased from 0 to 1, we assumed a 0.05 increase in bed scour for every 0.1 increase in peak flow and a 0.1 increase for every 1.0 increase in hydro-confinement. In this example the bed scour increased by 0.25. Bed Scour below Merwin Dam was reduced due to hydro-electric operation, which reduces peak flows.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—In watersheds that are rainfall dominated anchor ice and icing events do not occur. For elevations less than 1000 ft., EDT ratings of 0 were assigned to all reaches in the historical and current condition. For those from 1,000 to 2000 ft. EDT ratings of 1 were assigned. This was based on personal winter observation in the Wind River and discussions with CNFH staff. Since the Wind and EF Lewis River have the same headwaters. The same icing ratings were used in the Lewis River.

*Level of Proof*—Empirical observations were used to establish an elevation /icing relationship and this derived information was used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 0.0 -1.0 depending on the density of large trees and bank stability. Riparian zones with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating. Riparian function in most channel sections (EF above Lewisville and NF above Johnson) remains very functional except for lack of shade. Below these areas lack of connectivity, stability, and shade reduce function.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—Wood density was estimated during USFS and WDFW habitat surveys where density of wood equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. Due to their confinement, it was believed during high flows these reaches did not retain wood as well as other sections. When survey data was not available, wood densities were extrapolated from reaches with data. EDT Rating based on TFW standard of all wood. WDFW surveys suggest that the EDT wood rating in Rock Cr was 3. An EDT rating of 4 was observed in the mainstem Lewis River from Moulton to Rock Creek. For the remainder of the basin an average EDT rating of 3 was used. Additional USFS rating support poor wood for anadromous reaches above Sunset Falls.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) found that as road density increased by 1 $mi/mi^2$, fine sediment levels increased by 2.65%. However, Duncan and Ward (1985) found a lower increase in the percentage of fines in southwest Washington, but attributed much of the variation in fines to different geology. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 $mi/mi^2$ of roads for all watershed ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 $mi/mi^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored was excluded. Rather than use all three years of Layout Creek data , only the median was used and the final relationship used for EDT was 1.34% increase in fines per1 $mi/mi^2$ ($R^2$=0.56, n=15) (Figure E7-7).

During relicensing PacifiCorp analyzed spawning gravel below the Merwin Project and found fine sediment in spawning gravel that was very low and corresponded to and EDT rating of 0.5. For the remainder of the basin Lewis River road densities were obtained from URS (2003) report to the LCFRB and these were incorporated into the Wind River relationship to estimate fines.

Tidal reaches with lower gradients were given an EDT rating of 4.

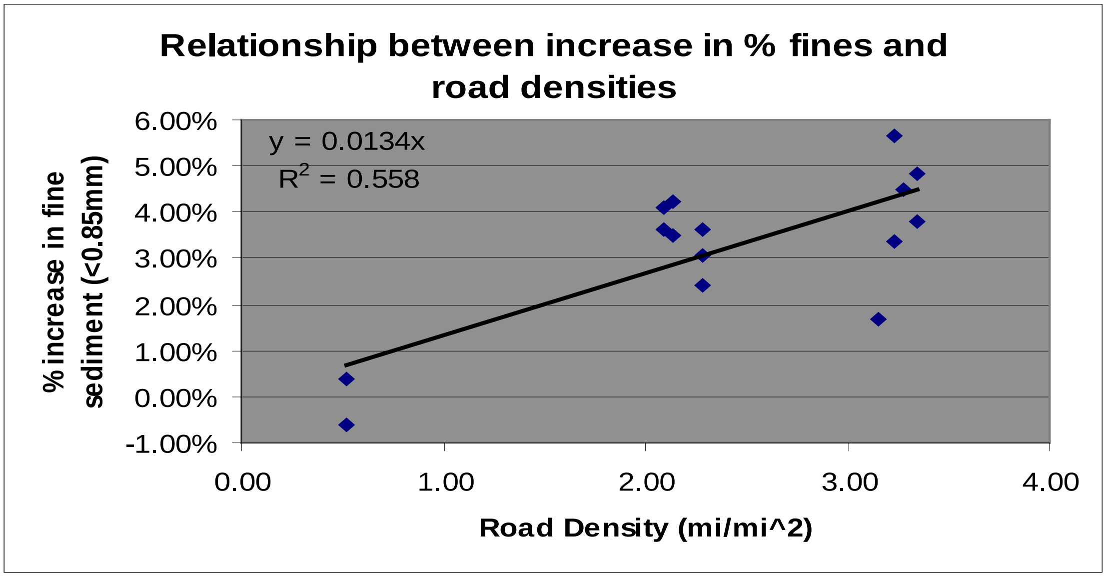


**Figure E7-7. Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), we assumed this level was the same for embeddedness, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

We assumed that the percent embeddedness was directly related to percentage of fines in spawning gravel. We used the Wind River data mentioned above to develop a scale relating road density to percent embeddedness and applied this to the Lewis River. Tidal reaches with lower gradients were given an EDT rating of 3.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process, that occasionally increases turbidity after an extensive hot burn. Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels to be an EDT rating of 0 in small tributaries, 0.3 in medium tributaries, and 0.5 in the mainstem.

Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout, Panther, and Middle Wind are over 40 mg/L, and other basins are 5-40mg/L, with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L level lasts 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for the lower mainstem. Since Lewis and Wind River subbasins were similar the Wind River ratings were applied to the Lewis River.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Temperature loggers have been extensively placed in the Wind River subbasin by USFS, USFWS, and USFWS. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern “TmpMonMax Rainfall”, TmpMonMax Groundwater“, and TmpMonMax Transitional" for the rainfall, groundwater and rain-on-snow-transitional watersheds, respectively.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

Historical temperatures are unknown the in the Lewis River subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—Derived information was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) – 5.8305 ( $R^2$= 0.32, n=27). This was used to generate categorical ratings (Table E7-44) based on elevation. For the Wind, we used actual data, where available, to develop non-categorical ratings. It should be noted that reaches with lakes/wetlands (Falls and EF Trout) and immediate downstream reaches have colder minimum temperatures (higher EDT ratings) and those with strong groundwater influence (Upper Trout) have warmer minimum temperatures (lower EDT ratings). Since Lewis and Wind River subbasins were similar the Wind River ratings were applied to the Lewis River.

**Table E7-44. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

The historic minimum temperature was assumed to be the same as current minimum temperatures. There is some support that historical minimum temperatures were warmer due to more mature forest stands, but we did not use this information due to the limited support and the fact that fire disturbance regimes in these forests would have periodically led to these conditions naturally.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established in the Wind. Expansion of empirical ratings was used for the remainder of the Wind and other basins.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Wind, Lower Washougal, Middle Washougal, NF Lewis, EF Lewis, Cedar, Kalama, Elochoman, and Grays Rivers using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. We used the mean July to September flow to determine the mean alkalinity values. For basins without flow data, we used mean summer alkalinity values. Alkalinity values were 22, 15, 12, 16, 20, 27, 21, 27, and 30 mg/L, respectively. EF Lewis alkalinity was estimated to be 20 mg/L at Heisson Gage based on conductivity measurements using Ptolmey (1993). All EF Lewis reaches were rated the same. NF Lewis was estimated to be 16 mg/L from Merwin sampling and all NF reaches were rated the same. Cedar Cr was estimated to be 17 mg/L from Summers (2003). All NF Lewis tributaries were rated same as Cedar Cr. For other basins, the standard basin alkalinity value was used. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—Derived information was used to estimate this attribute from conductivity measurements. Since alkalinity is did not vary much between adjacent basins and is believed to be relatively constant within a basin, estimated values were expanded for all reaches within a basin. Expert opinion was used to estimate the historical ratings for this attribute since historical data was lacking. The level of proof for the current condition is thoroughly established, generally accepted and good peer-reviewed empirical evidence in favor. For the historical data there is has a strong weight of evidence but not fully conclusive due to lack of data.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. Historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) and Summers (2001) reported that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August in Cedar Creek. All reaches in these watersheds were assumed to be unimpaired for dissolved oxygen. These are representative of free flowing reaches. The lower slough reaches in Hamilton, Hardy, EF Lewis, Kalama, and Coweeman are likely to have increased temperatures and lower DO levels in July/August.

*Level of Proof*—Empirical information and expert opinion were used to estimate the current and historical ratings for this attribute. Available current data support no problems with dissolved oxygen in flowing reaches. The level of proof for the current condition is thoroughly established, generally accepted and has good peer-reviewed empirical evidence in favor. In slough reaches, where no data was available, derived information and expert opinion was used. For the slough reaches and historical data there is has a strong weight of evidence but not fully conclusive due to lack of data. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off.

Nutrient enrichment throughout these watersheds was assumed to be non-existent or at low levels. Fertilizing by timber companies may have some minimal effect but it is likely that changes in nutrient levels from normal forest activities is near zero (WFPB 1997)

Potential low levels of nutrients from Merwin and Lewis River Hatcheries enter in the top of Lewis 7 and Lewis 6, respectively. Potential nutrient sources exist from homes and cabins with septic tanks and from cattle. The lower EF Lewis River and Cedar Creek have exceeded state water quality standards for fecal coliform. The mainstem Lewis River from Merwin to the mouth was rated as 1 due to hatchery and homes with septic tanks. The middle and lower portions of Cedar Creek and the Lower EF Lewis River were rated at 1, since sampling suggested thet exceeded state water quality standards. Other sites was assumed to be negligible and rated at 0.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Lower Wind, Upper Wind, Panther Creek, and Trout Creek (pers. com. Cochran, WDFW), (2) electro-shocking in 2002 by USFS and USGS in Upper Wind, Panther, and Trout & tributaries (pers. com. Connoly USGS, and Bair USFS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW snorkel surveys on the Wind and Panther (pers. com. Cochran, WDFW), (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). Lamprey, while present in the basin, are not included in the species count (Larry Lestelle pers com).

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Sloughs likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coastrange , reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW).

Anadromous salmonids had access to reaches above Merwin dam on the NF Lewis River. On EF lewis River chum dropped out at lower Rock Cr and all salmonids except steelhead dropped out at Lucia Falls. Only steelhead, cutthroat trout, whitefish, scuplins and lamprey accessed reaches above Lucia Falls.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

The tidal reaches have potential for use by exotic fishes from the Columbia River, as many as 12 species from the Columbia River may migrate into these reaches. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. Species introductions are due to warmwater fishes in the lower reaches of EF and NF Lewis Rivers. Lowest reaches were rated 3 based on derived info from other basins. Ratings were reduced above Woodland on NF Lewis River and Mason Cr. on EF Lewis River based on professional opinion and summer snorkel observations.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW). Hatcheries operate on NF Lewis below Merwin Dam and a second hatchery is located a few miles below the dam. Due to these hatchery releases and Remote Site Incubators in the tributaries all Lewis River and tributary reaches were rated at 4. Direct steelhead releases at Lewisville and Daybreak Park in the EF Lewis River were used as evidence to support and EDT rating of 4 for the lower EF Lewis River. The EF Lewis River and tributaries below Horseshoe were rated at a two due to steelhead hatchery straying. The Cedar Creek basin received a rating of three due to ongoing hatchery coho supplementation, and stray hatchery steelhead passing the Grist Mill fish ladder.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency. The two operating hatcheries on the NF Lewis River support and EDT rating of 3 in the upper reaches. The lowest reaches were reduced to a two due an assumed dilution of pathogens. NF Lewis tributaries including Cedar Creek were rated at a two due to RSI and the presence of stray hatchery salmon and steelhead. The EF Lewis River below Horseshoe Falls supported a rating of a two from hatchery steelhead releases in the lower EF Lewis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use (LewisvillePark on the EF Lewis River and on NF lewis River from Woodland to the dam); a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; 2 was given to reaches with multiple access points ( EF Lewis and tidal portions of the NF Lewis River) through public lands or unrestricted access through private lands; 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands ( undeveloped section of the EF lewis and tributaries with limited access); 0 was given to reaches with no roads and that are far from population centers .

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species is unknown in these watersheds. Predation risks increase on NF Lewis below hatcheries and EF Lewis below Lewisville Park, which is the (hatchery steelhead release site). These reaches were rated as a three. Cedar Creek coho smolt releases have been discontinued.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches). Historic spawning areas for chum, Chinook, coho in NF and EF Lewis up to Merwin Dam and EF Lewis -7 were rated as 0. NF and EF Lewis River tributaries with chum were rated as 2. Remaining basins were rated as 3 except above Luica Falls was rated as 4, since passage was restricted to steelhead.

Due to reduced abundance of salmon, the salmon carcass attribute was reduced. Since current escapement estimates for salmon occur in only index areas current estimates of carcass were based on professional opinion of spawning distribution. Recent nutrient enhancement programs have contributed surplus hatchery carcasses to some stream reaches. The recent programs were not included in the salmon carcass attribute. However, under recovery scenarios, they should be included.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. Slightly disturbed Rosgen B Channels in the Cowlitz and Grays had ratings of 0.1 to 1.4, but were very close to the averaged undisturbed rating of 0.6. Therefore, for current Rosgen B-channels we assumed the same rating as historic. For disturbed Rosgen C-channels in the Wind River the EDT benthos rating decreased to 1.5. Disturbed C-channels are likely to be more impacted by human activities due to their character than B-channels and the 1.5 EDT rating was used to describe current C-channels. Lower Cedar Creek has a rating B-IBI score of 2.6 or EDT score of 2.6. This reach is right below a disturbed C-Channel where the riparian encroachment has reduced shade, increased temperature, and nutrient levels (fecal coliform) have increased due to agriculture or septic tanks leaks.

B-IBI scores from the Wind River indicate little degradation for Rosgen B channels. Therefore, the 0.6 reference reach rating for current and historical reaches with confined channels. For C channels ratings were degraded to 1.6 based on Wind River data, which supported that B-IBI scores were reduced in less confined channels. Historical less confined channels in the lower basin were rated at 1, current rating was increased to 2 based on nutrients, water temps and DO. Lower Cedar Creek had B-IBI score of 2.6 Summers (2003). In Cedar Creek, reaches up to Chelatchie were feather to get to score of 1.0 for Cedar 6.

**Acknowledgements**

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Ecology, UCD, USFS, USGS, and OSU for providing their survey data, especially Brian Bair (USFS), Pat Connolly (USGS), and Shannon Claeson (OSU). We thank the staff at Mobrand Biometric Inc for assistance with the EDT model especially Kevin Malone, Jennifer Garrow, Greg Blair, and Rick Paquette.

# E.8. Bonneville Tributaries

## E.8.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for the Lower Columbia River Gorge tributaries. In this project we rated 23 reaches with 45 environmental attributes per reach for current conditions and another 45 for historical conditions. Over 2,000 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data. However, data is available from Gobar Creek (Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.8.2. Recommendations

1. Adult chum salmon population estimates should continue. However, more emphasis should be placed on determining the number of hatchery from the Duncan Creek re-introduction program and the reproductive success of hatchery spawners. Juvenile outmigrant counts are made at Duncan Creek and mark-recapture estimates in Hardy Creek and Hamilton Springs. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective. These programs should be maintained and improved as needed.
2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.
3. Empirical sediment data was only available for a few reaches and derived estimates were used for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.
4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.
5. Bed Scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.

6. USWFS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey a few representative reaches. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. Macro invertebrate sampling was not available. A combination of Ecology and OSU estimates of the Benthic Index of Biological Integrity (B-IBI) from the Wind River were used to develop EDT ratings in theWashougal Basin.
8. Obstructions were not rated and passage was assumed to be 100%. These ratings should be updated using the SSHIAP database.

## E.8.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This maximum elevation in these watershed is approximately 3,000 ft. The upper elevations are consistent with a rain-on-snow hydrologic regime and the lower elevations are consistent with a rainfall-dominated watershed. These subbasins were rated as rainfall dominated for the historic and current conditions because anadromous fish only access the lowest reaches. Groundwater influences are present in the Duncan Springs and Hamilton Springs spawning channels. These runoff patterns were used to shape estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watersheds, which did not have artificial flow regulation was given an EDT rating of 0 for the historical and current conditions. Hydro operations influence the Duncan Creek Outlet, Hardy 1, Hamilton 1, and Hamilton Slough. However, these are similar to natural variation due to Columbia River runoff patterns so left ratings at zero. Should fill out Hamilton Slough rating is influenced by BON operations.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Direct measures of inter-annual high flow variation are not available for this subbasin. Wind and White Salmon analysis of Q2yr suggests 12% and 10% increase in high flow (EDT rating of 2.2 to 2.3). USFS has conducted watershed analysis in the Gifford Pinchot streams (USFS 1996). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-45. Road densities from URS (2003) indicate Greenleaf, Upper Hamilton, Duncan, and Hardy/Woodward had densities of 4.2, 2.0, 3.4, and 3.8, respectively. However, Hardy Cr lies almost all with in State Park so road density are close to 1. USFS estimates support a slight peak flow increases for subbasins in Southwest Washington (Table E7-45). Peak flows were increased from 0% to 10% in subbasin reaches based on road densities.

**Table E7-45. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10 -12% |
| Rock Cr | | 1 -5% |
| Upper Kalama | | 5 - >10% |
| Cispus | | <10% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive (Spencer et al. 1996). Therefore, we rated the template and current conditions the same (EDT rating of 2). Low flows may be slightly lower in Duncan Sp, Hardy 2&3, and Hamilton 1&2 springs due to aggradation. However, this is speculative and historic and current ratings remained unchanged.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – Intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff for most of the basin. This attribute is influenced by the % impervious surfaces. Most reaches are influenced by forestry and impervious surfaces are low. We had no information on impervious surfaces but if information becomes available this attribute should be adjusted.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the remaining current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watersheds. USFS (1996) indicated peak flow may have increased by 13% in some subwatersheds. Since there was no data for this attribute, it was suggested that its rating should be the same as the changes in inter-annual variability in high flows (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification or water withdrawal was located within the reach. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement.

*Level of Proof*—A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof ranged from thoroughly established in reaches with direct observations to a strong weight of evidence in support but not fully conclusive in reaches were expanded information was used. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual "wetted width-high" values in reaches where data was available, and a 1.6 multiplier (60%) to expand "wetted width-low" values for reaches without high flow data. In canyon areas, summer flows were expanded by 20-40% depending of reach characteristics.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we

expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as percentage gradient) was calculated by dividing the change in reach elevation by the reach length. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

## Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed for confinement ratings (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings (Table E7-46).

**Table E7-46. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and Limiting Factors Analysis (LFA) to estimate EDT ratings. Ratings were categorical due to the lack of field surveys to corroborate GIS, map, and photo estimates. Hydroconfinement areas include the lower portion of Hardy Creek, the riprap in North Bonneville along Hamilton Creek.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter). Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower reaches inundated by the construction of Bonneville Dam were rated as glides and pools depending on the amount of inundation.

WDFW habitat surveys followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore it was estimated but not surveyed by WDFW.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (WFPB 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we assumed pool habitats were in the "good" range and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. These low gradient C channels were assigned up to a 15% off-channel habitat factor, historically and 0% currently. Off-channel habitat is not significant except in the lower reaches. These reaches were assigned an EDT rating of up to 15% historic off-channel habitat factor due to the backwater of the Columbia River and assumed beaver populations. Old photographs suggested that substantial off-channel habitat was historically present.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. In most cases known fish distribution stopped at all barriers. In some cases, where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. Most watersheds in this unit are forested with residential use in the lower portion of the subbasin. Water withdrawals occur in Jones & Boulder Creek for city water, and at WDFW Hatcheries. These reaches were rated at a 2. Some irrigation withdrawals occur for personal use were noted during summer in the mainstem below the WF Washougal and in the Little Washougal. These small withdrawals were rated at a one. The mill in Camas withdraws water but its mouth was outside the Washougal River.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table is based on professional judgment and relates bed scour to confinement, wetted width (high flow), and gradient. It assumes bed scour increases as gradient, wetted width, and confinement increase. For low gradient slough like reaches, we reduced the bed scour rating to ~1, since these reaches are unconfined and influenced by the Columbia River.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as peak flow and hydro-confinement increased. For example, if in the template condition a reach had a peak flow of 2.0 and in the current condition peak flow increased to 2.3, while hydro-confinement ratings increased from 0 to 1, we assumed a 0.05 increase in bed scour for every 0.1 increase in peak flow and a 0.1 increase for every 1.0 increase in hydro-confinement. In this example the bed scour increased by 0.25.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—In watersheds that are rainfall dominated anchor ice and icing events do not occur. For elevations less than 1000 ft., EDT ratings of 0 were assigned to all reaches in the historical and current condition. For those from 1,000 to 2000 ft. EDT ratings of 1 were assigned. This was based on personal winter observation in the Wind River and discussions with CNFH staff. Since the Gorge tributaries are adjacent to the Wind River, the same icing ratings were used in the Gorge tributaries.

*Level of Proof*—Empirical observations were used to establish an elevation /icing relationship and this derived information was used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 0.0 -1.0 depending on the density of large trees and bank stability. Riparian zones with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating.

Riparian in upper most reaches (above HWY 14) in Hamilton and Hardy is in mature forest with much in state park and is in excellent condition. The lower end of Hamilton and Duncan Creeks, which pass through North Bonneville and Skamania Landing, respectively, are degraded and rated as a 2.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and

Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—Wood density was estimated during USFS and WDFW habitat surveys where density of wood equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. Due to their confinement, it was believed during high flows these reaches did not retain wood as well as other sections. When survey data was not available, wood densities were extrapolated from reaches with data. EDT Rating based on TFW standard of all wood. Currently, there is limited data for wood on the Washougal River. Surveys of mainstem reaches in other system suggest values of 3 and 4 for most larger mainstem areas and values of 2 to 3 for tributaries. Base on consultation with biologists from WDFW, PSMFC, and WDFW, these ratings were then applied to the Gorge tributaries. These rating suggest a significant loss of wood.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) found that as road density increased by 1 mi/mi$^2$, fine sediment levels increased by 2.65%. However, Duncan and Ward (1985) found a lower increase in the percentage of fines in southwest Washington, but attributed much of the variation in fines to different geology. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 mi/mi$^2$ of roads for all watershed ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 mi/mi$^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored was excluded. Rather than use all three years of Layout Creek data , only the median was used and the final relationship used for EDT was 1.34% increase in fines per1 mi/mi$^2$ ($R^2$=0.56, n=15) (Figure E7-8). Road densities were obtained from URS (2003) report to the LCFRB and these were incorporated into the Wind River relationship to estimate fines. Tidal reaches with lower gradients were rated one point higher.

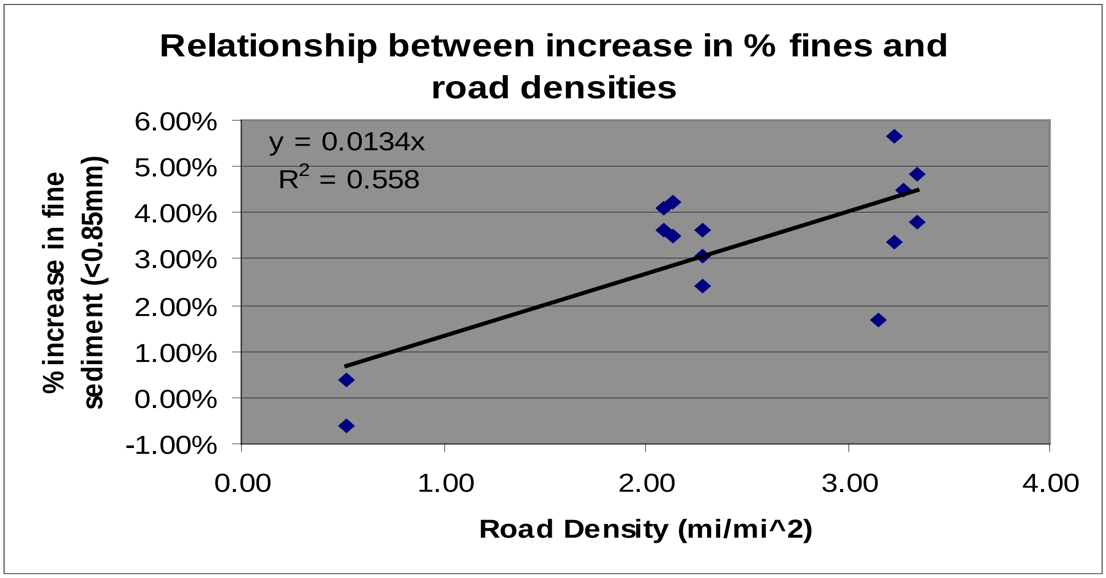


**Figure E7-8. Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), we assumed this level was the same for embeddedness, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

We assumed that the percent embeddedness was directly related to percentage of fines in spawning gravel. We used the Wind River data mentioned above to develop a scale relating road density to percent embeddedness and applied this to the Gorge tributaries. Tidal reaches with lower gradients were rated one point higher.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process, that occasionally increases turbidity after an extensive hot burn. Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels to be an EDT rating of 0 in small tributaries, 0.3 in medium tributaries, and 0.5 in the mainstem.

Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout, Panther, and Middle Wind are over 40 mg/L, and other basins are 5-40mg/L, with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L level lasts 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for the lower mainstem. Since Gorge tributaries and Wind River subbasins were similar, the Wind River ratings were applied to the Gorge tributaries.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Temperature loggers have been extensively placed in the Gorge subbasin by USFWS and WDFW. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern “TmpMonMax Rainfall”, TmpMonMax Groundwater“, and TmpMonMax Transitional” for the rainfall, groundwater and rain-on-snow-transitional watersheds, respectively.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

Historical temperatures are unknown the in this subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—Derived information was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) – 5.8305 ( $R^2$= 0.32, n=27). This was used to generate categorical ratings (Table E7-47) based on elevation. For the Wind, we used actual data, where available, to develop non-categorical ratings. It should be noted that reaches with lakes/wetlands (Falls and EF Trout) and immediate downstream reaches have colder minimum temperatures (higher EDT ratings) and those with strong groundwater influence (Upper Trout) have warmer minimum temperatures (lower EDT ratings). Since Gorge tributaries and Wind River subbasins were similar, the Wind River ratings were applied to the Gorge tributaries.

**Table E7-47. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

The historic minimum temperature was assumed to be the same as current minimum temperatures. There is some support that historical minimum temperatures were warmer due to more mature forest stands, but we did not use this information due to the limited support and the fact that fire disturbance regimes in these forests would have periodically led to these conditions naturally.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established in the Wind. Expansion of empirical ratings was used for the remainder of the Wind and other basins.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Wind, Lower Washougal, Middle Washougal, NF Lewis, EF Lewis, Cedar, Kalama, Elochoman, and Grays Rivers using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. We used the mean July to September flow to determine the mean alkalinity values. For basins without flow data, we used mean summer alkalinity values. Alkalinity values were 22, 15, 12, 16, 20, 27, 21, 27, and 30 mg/L, respectively. The Wind River alkalinity data was used because no alkalinity readings were available for this subbasin. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—Derived information was used to estimate this attribute from conductivity measurements. Since alkalinity is did not vary much between adjacent basins and is believed to be relatively constant within a basin, estimated values were expanded for all reaches within a basin. Expert opinion was used to estimate the historical ratings for this attribute since historical data was lacking. The level of proof for the current condition is thoroughly established, generally accepted and good peer-reviewed empirical evidence in favor. For the historical data there is has a strong weight of evidence but not fully conclusive due to lack of data.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. No data was available for this subbasin. Historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) and WDFW hatchery data found that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All reaches in these watersheds were assumed to be unimpaired for dissolved oxygen.

*Level of Proof*—Empirical information and expert opinion were used to estimate the current and historical ratings for this attribute. Available current data support no problems with dissolved oxygen in flowing reaches. The level of proof for the current condition is thoroughly established, generally accepted and has good peer-reviewed empirical evidence in favor. In slough reaches, where no data was available, derived information and expert opinion was used. For the slough reaches and historical data there is has a strong weight of evidence but not fully conclusive due to lack of data. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off. The potential for an increase in nutrients from septic tanks is possible around Duncan Lake and outlet. Therefore these reaches were rated as 1. Assumed all other reaches are similar to historic levels.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Lower Wind, Upper Wind, Panther Creek, and Trout Creek (pers. com. Cochran, WDFW), (2) electro-shocking in 2002 by USFS and USGS in Upper Wind, Panther, and Trout & tributaries (pers. com. Connoly USGS, and Bair USFS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW snorkel surveys on the Wind and Panther (pers. com. Cochran, WDFW), (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). Lamprey, while present in the basin, are not included in the species count (Larry Lestelle pers com).

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Sloughs likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coast range , reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this - it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW).

Fish community richness has increased due to species introduction. These are warmwater and coolwater fishes from the Columbia River. The have access up to Duncan Lake, Hamilton 1, and Hardy1.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

The tidal reaches have potential for use by exotic fishes from the Columbia River, as many as 12 species from the Columbia River may migrate into these reaches. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. Species introductions are due to warmwater fishes in the lower reaches of Gorge tributaries. Lowest reaches were rated 3 based on derived info from other basins. Ratings were reduced above this site based on professional opinion, USFS, and USGS electroshocking data.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW). The current stocking program for chum salmon was initiated in Duncan Creek in 2001. Steelhead plants were discontinued in 1998 in Hamilton Creek. Both these programs were rated as 3.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency. Based on stocking of steelhead in Hamilton Creek and Chum Salmon in Duncan Springs, these reaches and downstream reaches were rated as a 2. All other reaches were as rated as a zero.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use (residences adjacent to Duncan Lake and lower Hamilton Creek); a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; 2 was given to reaches with multiple access points ( most other reaches near highway 14) through public lands or unrestricted access through private lands; 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands ( Hardy Creek); 0 was given to reaches with no roads and that are far from population centers ( headwater roadless areas).

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Predation has increased in reaches connected to Columbia, Duncan Lake, and Greenleaf Slough due to warmwater and coolwater species introductions. Predation risks increased due to introduced fish moving up from the Columbia River.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches). Chum salmon are the most abundant anadromous salmonid and access reaches up to Highway 14. Current estimates of carcasses were derived from estimates of chum salmon escapement.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. Slightly disturbed Rosgen B Channels in the Cowlitz and Grays had ratings of 0.1 to 1.4, but were very close to the averaged undisturbed rating of 0.6. Therefore, for current Rosgen B-channels we assumed the same rating as historic. For disturbed Rosgen C-channels in the Wind River the EDT benthos rating decreased to 1.5. Disturbed C-channels are likely to be more impacted by human activities due to their character than B-channels and the 1.5 EDT rating was used to describe current C-channels. Lower Cedar Creek has a rating B-IBI score of 2.6 or EDT score of 2.6. This reach is right below a disturbed C-Channel where the riparian encroachment has reduced shade, increased temperature, and nutrient levels (fecal coliform) have increased due to agriculture or septic tanks leaks.

B-IBI scores from the Wind River indicate little degradation for Rosgen B channels. Therefore, the 0.6 reference reach rating for current and historical reaches with confined channels. For C channels ratings were degraded to 1.6 based on Wind River data, which supported that B-IBI scores were reduced in less confined channels. Historical less confined channels in the lower basin were rated at 1, current rating was increased to 2 based on nutrients, water temps and DO.

#### Acknowledgements

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Ecology, UCD, USFS, USGS, and OSU for providing their survey data, especially Brian Bair (USFS), Pat Connolly (USGS), and Shannon Claeson (OSU). We thank the staff at Mobrand Biometric Inc for assistance with the EDT model especially Kevin Malone, Jennifer Garrow, Greg Blair, and Rick Paquette.

# E.9. Washougal River

## E.9.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treament Model (EDT) for the Washougal River. In this project we rated 64 reaches with 45 environmental attributes per reach for current conditions and another 45 for historical conditions. Over 2,700 current ratings were assigned and empirical observations within these reaches were not available for all of these ratings. In fact less than 20% of these ratings are from empirical data. To develop the remaining data, we used expansion of empirical observations, derived information, expert opinion, and hypothetical information. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute, data was very limited or non-existent. WDFW established a relationship between road density and fine sediment in the Wind River. We applied this relationship to all subwatersheds; this is an example of derived information. In some cases, such as bed scour, we had no data. However, data is available from Gobar Creek (Kalama River tributary) and observations have been made in the Wind River as to which flows produce bed load movement. We noted that bed scour is related to gradient, stream width, and confinement. Based on these observations expert opinion was used to develop a look-up table to estimate bed scour. For rationale behind the EDT ratings assigned, see the text below. For specific reach scale information, please see the EDT database for the watershed of interest. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.9.2. Recommendations

1. Adult chum salmon, Chinook salmon, and steelhead population estimates should continue. However, more emphasis should be placed on determining the number of hatchery and wild spawners and the reproductive success of hatchery spawners. Summer steelhead estimates are based on mark-recapture and are considered accurate and precise. Winter steelhead, fall Chinook estimates and chum salmon estimates are based on an assumed observer efficiency and are likely to be less reliable. Coho salmon counts are periodic and not population estimates. Summer steelhead escapement estimates should be continued and funding secured to develop accurate and precise adult estimates. Juvenile outmigrant estimates are not made and should be funded. Accurate and precise adult and juvenile population estimates will allow for better population status estimates, validation of EDT, and to determine if subbasin restoration actions are effective. These programs should be maintained and improved as needed.
2. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating as would field surveys.
3. Empirical sediment data was only available for a few reaches and derived estimates were used for most of the basin. A sediment monitoring program should be developed to assess the percentage of fines in spawning gravels, embeddedness, and turbidity in reaches used by anadromous fish.
4. Differences existed between field and GIS ratings of natural confinement. The SSHIAP database should be field verified.

5. USGS Gauge stations are no longer operating in this subbasin. Gauges should be re-installed. Bed Scour estimates were not available for this basin and bed scour data should be collected and related to peak flows.
6. USFS habitat surveys do not directly measure all habitat types needed for EDT. WDFW habitat surveys in 2002 were opportunistic; that is, based on a limited amount of resources, we chose to survey a few representative reaches. To accurately estimate stream habitat type within the anadromous distribution, a statistically valid sampling design should be developed and applied (Hankin and Reeves1988 or EMAP). Survey methodology should differentiate between pools and glides and be repeatable.
7. Macro invertebrate sampling was not available. A combination of Ecology and OSU estimates of the Benthic Index of Biological Integrity (B-IBI) from the Wind River were used to develop EDT ratings in theWashougal Basin.
8. Obstructions were not rated and passage was assumed to be 100%. These ratings should be updated using the SSHIAP database.

## E.9.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This maximum elevation in this watershed is approximately 3,000 ft. The upper elevations are consistent with a rain-on-snow hydrologic regime and the lower elevations are consistent with a rainfall-dominated watershed. This subbasin was rated as rainfall dominated for the historic and current conditions except for upper portions on the mainstem above Duggan Falls and WF we assumed a rain-on-snow pattern. These runoff patterns were used to shape estimates of flow and temperature in the EDT model.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—This watersheds, which did not have artificial flow regulation was given an EDT rating of 0 for the historical and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Direct measures of inter-annual high flow variation are not available for most subwatersheds in the Washougal River. The Q2yr flow calculation on the Washougal increased 17% from 1945 to 1981 and EDT rating of 2.4. The Washougal above Prospector Creek is a roadless area and was rated at 2.0. Some roads along the Washougal below Prospector Creek, and in Timber and Stebbins Creeks increase the rating to a 2.1. In the mainstem from Dugan Cr to WF Washougal, the rating was increased to 2.2. The West Fork was assumed to be 2.3. Mainstem from WF Washougal to Mouth, which covers the USGS gauge location, was rated 2.4. All other tributaries were assumed to be 2.2 except the Little Washougal River and Lacamas Creek, which were assumed to be 2.4 and 2.5, respectively.

USFS has conducted watershed analysis in the EF Lewis (USFS 1996). Peak flow analysis was conducted using the State of Washington "Standard methodology for conducting watershed analysis". The primary data used for the peak flow analysis is vegetation condition, elevation, road network, and aspect. The results for increased risk in peak flow from the USFS watershed analysis are shown in Table E7-48. USFS estimates support peak flow increases for subbasins in Southwest Washington.

**Table E7-48. Summary of USFS Watershed Analysis for the change in peak flow**

| Basin | # of Subbasins | Increase in Peak Flow |
|---|---|---|
| Wind | 26 | 2 – 14% |
| East Fork Lewis | 9 | 5 –13% |
| Lower Lewis | | 10 -12% |
| Rock Cr | | 1 -5% |
| Upper Kalama | | 5 - >10% |
| Cispus | | <10% |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Research on the effects of land use practices on summer low flow is inconclusive (Spencer et al. 1996). Therefore, we rated the template and current conditions the same (EDT rating of 2). Water withdrawals in Jones and Boulder Creeks to supply water for Camas and these reaches received a rating of 4. Occasional water withdrawals for residential use was not factored into the EDT rating.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. This attribute was given an EDT rating of 0 for the current conditions due to the lack of storm water runoff for most of the basin. This attribute is influenced by the % impervious surfaces. Most reaches are influenced by forestry and impervious surfaces are low. The exception for this is occurs in the lower river. We had no information on impervious surfaces but if information becomes available this attribute should be adjusted.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the remaining current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in these watersheds. USFS (1996) indicated peak flow may have increased by 13% in some subwatersheds. Since there was no data for this attribute, it was suggested that its rating should be the same as the changes in inter-annual variability in high flows (pers. com. Larry Lestelle, Mobrand, Inc).

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—Ned Pittman (WDFW) provided the length of each reach from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification or water withdrawal was located within the reach. Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2002 (VanderPloeg 2003). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement.

*Level of Proof*—A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof ranged from thoroughly established in reaches with direct observations to a strong weight of evidence in support but not fully conclusive in reaches were expanded information was used. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Wetted widths corresponding to average winter high flows (January) were measured as part of these surveys (VanderPloeg 2003). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Typically less reaches per subbasin were measured during average winter flow as compared to summer flow. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used actual "wetted width-high" values in reaches where data was available, and a 1.6 multiplier (60%) to expand "wetted width-low" values for reaches without high flow data. In canyon areas, summer flows were expanded by 20-40% depending of reach characteristics.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we

expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

## Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as percentage gradient) was calculated by dividing the change in reach elevation by the reach length. Ned Pittman (WDFW) used SSHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical gradient.

## Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed for confinement ratings (VanderPloeg 2003). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4. There are often multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings (Table E7-49).

**Table E7-49. Comparison of SSHIAP and EDT ratings for confinement.**

| Project | Unconfined | Equal unconfined and mod. confined | Moderately confined | Equal mod confined and confined | Confined |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Confinement – hydro-modifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cut off due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP digital ortho-photos, USGS maps, and Limiting Factors Analysis (LFA) to estimate EDT ratings. Ratings were categorical due to the lack of field surveys to corroborate GIS, map, and photo estimates. Hydroconfinement primarily occurs in the lower river due to dikes and filling in of side channels. The Washougal River road also increases confinement in some sections.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition—Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter). Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches in lower Columbia River tributaries were surveyed by WDFW in 2003 (VanderPloeg 2003). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower reaches inundated by the construction of Bonneville Dam were rated as glides and pools depending on the amount of inundation.

WDFW habitat surveys followed USFS stream survey level 2 protocols, which delineate between riffles and slow water but not pools and glides. Glide habitat is the most difficult habitat to identify, therefore it was estimated but not surveyed by WDFW.

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (WFPB 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we assumed pool habitats were in the "good" range and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis. These low gradient C channels were assigned up to a 15% off-channel habitat factor, historically and 0% currently. Off-channel habitat is not significant in the Washougal River except in the lower reaches. These reaches were assigned an EDT rating of up to 75% historic off-channel habitat factor due to the backwater of the Columbia River and assumed beaver populations. Old photographs suggested that substantial off-channel habitat was historically present.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. In most cases known fish distribution stopped at all barriers. In some cases, where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. Most watersheds in this unit are forested with residential use in the lower portion of the subbasin. Water withdrawals occur in Jones & Boulder Creek for city water, and at WDFW Hatcheries. These reaches were rated at a 2. Some irrigation withdrawals occur for personal use were noted during summer in the mainstem below the WF Washougal and in the Little Washougal. These small withdrawals were rated at a one. The mill in Camas withdraws water but its mouth was outside the Washougal River.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table is based on professional judgment and relates bed scour to confinement, wetted width (high flow), and gradient. It assumes bed scour increases as gradient, wetted width, and confinement increase. For low gradient slough like reaches, we reduced the bed scour rating to ~1, since these reaches are unconfined and influenced by the Columbia River.

Current EDT ratings were developed and used as the baseline for scour in the current condition. Template ratings for bed scour were increased as peak flow and hydro-confinement increased. For example, if in the template condition a reach had a peak flow of 2.0 and in the current condition peak flow increased to 2.3, while hydro-confinement ratings increased from 0 to 1, we assumed a 0.05 increase in bed scour for every 0.1 increase in peak flow and a 0.1 increase for every 1.0 increase in hydro-confinement. In this example the bed scour increased by 0.25.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—In watersheds that are rainfall dominated anchor ice and icing events do not occur. For elevations less than 1000 ft., EDT ratings of 0 were assigned to all reaches in the historical and current condition. For those from 1,000 to 2000 ft. EDT ratings of 1 were assigned. This was based on personal winter observation in the Wind River and discussions with CNFH staff. Since the Wind and Washougal Rivers have the same headwaters, the same icing ratings were used in the Washougal River.

*Level of Proof*—Empirical observations were used to establish an elevation /icing relationship and this derived information was used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. Riparian zones with mature conifers are rated at 0.0 -1.0 depending on the density of large trees and bank stability. Riparian zones with saplings and deciduous trees are rated as 1.5 due to lack of shade and bank stability. Riparian zones with brush and few trees would be rated as 2. For an EDT rating to exceed 2, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees it should have a score of 2 or better. Most current vegetated riparian zones with no hydro-confinement should be rated as a 1 to 1.5. When hydro-confinement exists rating from rules on hydro-confinement were used to increase the riparian rating. Ratings also increased based on lack of vegetation. Key reaches were established for current riparian function through out these watersheds. Other reaches were referenced to these key reaches to develop a final EDT rating.

Many reaches in the upper Washougal are still recovering form Yaclot Burn. These reaches given 0-1. Reaches with housing development between Dugan Falls and the WF Washougal were given a rating of 1.5, since most housing encroachment is at the edge of riparian and elevated from stream banks. The area from the WF Washougal to Little Washougal was rated a 2, due to increased housing and roads in riparian. Reaches below WF given 3 due to roads, houses, and dikes. Little Washougal was rated from 3 in the lower developed reaches to 1 near the headwaters. Other tributaries have minimal development in riparian and were rated between a 1 and 2, depending on the level of riparian disturbance.

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.

*Rationale*—Wood density was estimated during USFS and WDFW habitat surveys where density of wood equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches except large Canyon sections on the Grays, Coweeman, Kalama, EF Lewis, Washougal, and Wind, which are assumed to be 2. Due to their confinement, it was believed during high flows these reaches did not retain wood as well as other sections. When survey data was not available, wood densities were extrapolated from reaches with data. EDT Rating based on TFW standard of all wood. Currently, there is limited data for wood on the Washougal River. Surveys of mainstem reaches in other system suggest values of 3 and 4 for most larger mainstem areas. Values of 2 to 3 for tributaries. These ratings were then applied to the Washougal River.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expanded empirical observations were used to estimate the ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Fine Sediment (intragravel)

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992). The average percentage of fines (8.5%) was used, which corresponds to an EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3.

To rate percentage of fines in the current condition, a scale was developed relating road density to fines. Rittmueller (1986) found that as road density increased by 1 mi/mi$^2$, fine sediment levels increased by 2.65%. However, Duncan and Ward (1985) found a lower increase in the percentage of fines in southwest Washington, but attributed much of the variation in fines to different geology. USFS used a McNiel core to collect gravel samples from 1998 to 2000 in 8 subwatersheds in the Wind River subbasin. Fines were defined as less than 0.85mm. A regression was run comparing the percentage for each year to road densities. The increase was 1.04% per 1 mi/mi$^2$ of roads for all watershed ($R^2$ = 0.31, n=17). The increase was 1.52% per 1 mi/mi$^2$ for all watersheds ($R^2$= 0.73, n= 14) when Layout Creek, which was recently restored was excluded. Rather than use all three years of Layout Creek data , only the median was used and the final relationship used for EDT was 1.34% increase in fines per1 mi/mi$^2$ ($R^2$=0.56, n=15) (Figure E7- 9). Road densities were obtained from URS (2003) report to the LCFRB and these were incorporated into the Wind River relationship to estimate fines. Tidal reaches with lower gradients were rated one point higher.

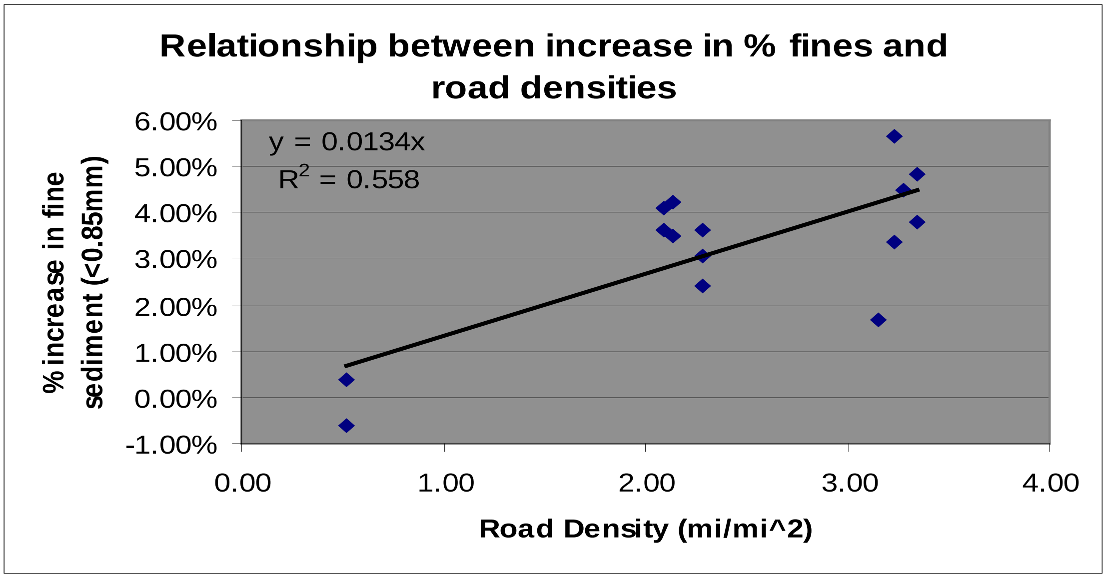


**Figure E7- 9. Relationship between road densities and the percentage increase in fines (<0.85mm) from USFS data.**

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

## Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— In the template (pristine) condition, SW Washington watersheds were assumed to have a low level of embeddedness. Based on the historic level of fines in spawning gravels (8.5%), we assumed this level was the same for embeddedness, which corresponds to and EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

We assumed that the percent embeddedness was directly related to percentage of fines in spawning gravel. We used the Wind River data mentioned above to develop a scale relating road density to percent embeddedness and applied this to the Washougal River. Tidal reaches with lower gradients were rated one point higher.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. No historical information is available for this attribute. Fire was historically a natural disturbance process that occasionally increases turbidity after an extensive hot burn. Current increases in turbidity are likely associated with human activities that lead to bank instability in the riparian area and roads associated with logging, urbanization, and agriculture. Background turbidity levels were assumed to increase with stream size. Professional opinion set these levels to be an EDT rating of 0 in small tributaries, 0.3 in medium tributaries, and 0.5 in the mainstem.

Suspended sediment and turbidity data is limited to grab samples by USFS and UCD for the Wind River. Flow data and limited turbidity data are available for the Elochoman River from the USGS website (http://wa.water.usgs.gov/realtime/historical.html). Historical turbidity data was plotted versus flow data from the same time period. Prior to 1978, USGS turbidity data was recorded in JTU. Since 1978, turbidity data has been recorded in NTU. There is not a direct conversion from JTU to NTU, making it difficult to interpret turbidity data prior to 1978. Bank stability and roads analyses support a small increase in turbidity. Limited data suggests during high water events Wind River suspended sediment exceeds 100 mg/L, while Lower Trout, Panther, and Middle Wind are over 40 mg/L, and other basins are 5-40mg/L, with most less than 25mg/L. However, the duration of these turbidity levels is unknown. If levels of 100mg/L last for 24 hours the EDT rating is 1.0. If the 25 mg/L level lasts 24 hours, the EDT rating is 0.8. These provided the basis for current ratings. These generally support ratings of 0.3 for small tributaries, 0.7 for larger tributaries, and 1.0 for the lower mainstem. Since Washougal and Wind River subbasins were similar the Wind River ratings were applied to the Washougal River.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Temperature loggers have been extensively placed in the Washougal River subbasin by CSF and WDFW. This data was entered into the EDT temperature calculator provided by Mobrand, Inc. to produce EDT ratings for August. To develop maximum temperature ratings for the remaining months, we used the template monthly pattern "TmpMonMax Rainfall", TmpMonMax Groundwater", and

TmpMonMax Transitional" for the rainfall, groundwater and rain-on-snow-transitional watersheds, respectively.

The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If temperature loggers were mid-reach we used the reading for the entire reach. If temperature loggers were at the end of the reach and evidence from other temperature loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches without temperature loggers located between reaches with temperature loggers – ratings from reaches with temperature loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to estimate the rating for the reaches downstream.

Historical temperatures are unknown the in the Lewis River subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—Derived information was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations and expansion of empirical observations was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Wind River temperature data was used to develop a relationship between elevation and maximum temperature for elevations up to 2000 feet as follows: EDT min temp = 1.0248 Ln(elev) – 5.8305 ( $R^2$= 0.32, n=27). This was used to generate categorical ratings (Table E7-50) based on elevation. For the Wind, we used actual data, where available, to develop non-categorical ratings. It should be noted that reaches with lakes/wetlands (Falls and EF Trout) and immediate downstream reaches have colder minimum temperatures (higher EDT ratings) and those with strong groundwater influence (Upper Trout) have warmer minimum temperatures (lower EDT ratings). Since Washougal and Wind River subbasins were similar, the Wind River ratings were applied to the Washougal River.

**Table E7-50. Estimated categorical ratings for minimum temperature based on elevation from Wind River data.**

| Elevation | EDT Rating |
|---|---|
| < 600 ft | 0 |
| 600-1200 | 1 |
| 1300-3000 ft | 2 |

The historic minimum temperature was assumed to be the same as current minimum temperatures. There is some support that historical minimum temperatures were warmer due to more mature forest stands, but we did not use this information due to the limited support and the fact that fire disturbance regimes in these forests would have periodically led to these conditions naturally.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established in the Wind. Expansion of empirical ratings was used for the remainder of the Wind and other basins.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. These reaches were given an EDT rating of 1. Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were given an EDT rating of 2. We could not find any data on the current or historical conditions for ground water input. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2. Higher gradient reaches in the upper watershed are likely similar to the historic condition and were given an EDT rating of 2.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*—Alkalinity was estimated from historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) for conductivity on the Wind, Lower Washougal, Middle Washougal, NF Lewis, EF Lewis, Cedar, Kalama, Elochoman, and Grays Rivers using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). A relationship was developed between flow and alkalinity assuming a power function. We used the mean July to September flow to determine the mean alkalinity values. For basins without flow data, we used mean summer alkalinity values. Alkalinity values were 22, 15, 12, 16, 20, 27, 21, 27, and 30 mg/L, respectively.

USGS sampling suggest a rating of 15 and 12 mg/L for Lower and Middle reaches of the Washougal River, which translate to EDT ratings of 1.7 and 1.5. These were expanded to appropriate reaches. Alkalinity in the historic condition was given the same value as the current condition.

*Level of Proof*—Derived information was used to estimate this attribute from conductivity measurements. Since alkalinity is did not vary much between adjacent basins and is believed to be relatively constant within a basin, estimated values were expanded for all reaches within a basin. Expert opinion was used to estimate the historical ratings for this attribute since historical data was lacking. The level of proof for the current condition is thoroughly established, generally accepted and good peer-reviewed empirical evidence in favor. For the historical data there is has a strong weight of evidence but not fully conclusive due to lack of data.

### Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen in the template (historic) condition was assumed to be unimpaired. Historical USGS data (www.wa.water.usgs.gov/realtime/historical.html) and WDFW hatchery data found that in surveyed creeks dissolved oxygen levels were greater than 8 mg/l in August. All reaches in these watersheds were assumed to be unimpaired for dissolved oxygen.

*Level of Proof*—Empirical information and expert opinion were used to estimate the current and historical ratings for this attribute. Available current data support no problems with dissolved oxygen in flowing reaches. The level of proof for the current condition is thoroughly established, generally accepted and has good peer-reviewed empirical evidence in favor. In slough reaches, where no data was available, derived information and expert opinion was used. For the slough reaches and historical data there is has a strong weight of evidence but not fully conclusive due to lack of data. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support due to the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited. Historically nutrient enrichment did not occur because watersheds were in the "pristine" state. To determine the amount of nutrient enrichment in various reaches the following factors were examined: fertilizing by timber companies, reaches downstream from hatcheries, agriculture effects, septic tanks, and storm water run-off.

Nutrient enrichment throughout these watersheds was assumed to be non-existent or at low levels. Fertilizing by timber companies may have some minimal effect but it is likely that changes in nutrient levels from normal forest activities is near zero (WFPB 1997). Assumed nutrient enhancement from a dairy in Little Washougal increased EDT ratings to 2. Reaches with hatcheries and septic systems along river had EDT ratings of 1. Other sites was assumed to be negligible and rated at 0.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data. Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists/hatchery personnel familiar with these areas, and local knowledge. Anadromous fish distribution was estimated from the above as well as the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in SW Washington watersheds: (1) smolt trapping activities on Lower Wind, Upper Wind, Panther Creek, and Trout Creek (pers. com. Cochran, WDFW), (2) electro-shocking in 2002 by USFS and USGS in Upper Wind, Panther, and Trout & tributaries (pers. com. Connoly USGS, and Bair USFS), (3) electroshocking by WDFW in many SW Washington tributaries (pers. com. Hallock, WDFW), (4) WDFW snorkel surveys on the Wind and Panther (pers. com. Cochran, WDFW), (5) species present in Hardy Slough (pers. com. Coley, USFWS), (6) Reimers and Bond (1967), and (7) McPheil (1967). Lamprey, while present in the basin, are not included in the species count (Larry Lestelle pers com).

A spreadsheet summarizing the above data sources was developed: (EDT 2003 Data.xls pers. com. Glaser WDFW). Sloughs likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, coho, steelhead/rainbow, cutthroat, sculpin sp(3) ( torrent, coastrange , reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced. The eastern banded killifish is an exception to this, it has been found in higher reaches of the Elochoman River (pers. com. Byrne, WDFW) and trapped on Abernathy Creek (pers. com. Hanratty, WDFW).

On Washougal River chum dropped out the Little Washougal, Chinook salmon at Salmon Falls, and coho salmon at Duggan Falls. All salmonids except steelhead dropped out at Duggan Falls. Only steelhead, cutthroat trout, scuplins and lamprey accessed reaches above Duggan Falls.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above).

The tidal reaches have potential for use by exotic fishes from the Columbia River, as many as 12 species from the Columbia River may migrate into these reaches. An estimated 12 species were included in this list: large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. Species introductions are due to warmwater fishes in the lower reaches in the Washougal River. Lowest reaches were rated 3 based on derived info from other basins. Ratings were reduced above this site based on professional opinion and summer snorkel observations.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency (pers. com. Glaser, WDFW). Hatchery steelhead are released at Skamania Hatchery. The distribution of hatchery steelhead continues up the WF Washougal River but snorkel survey data suggest steelhead do not move past mouth of WF Washougal River in mainstem. The Washougal Salmon Hatchery releases coho and fall Chinook salmon, which access all areas below Duggan Falls. A hatchery coho program is operated on Little Washougal River. This distribution information was used to develop ratings for this attribute.

*Level of Proof*—For current and historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of zero. Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency. ). Hatchery steelhead are released at Skamaina Hatchery. The distribution of hatchery steelhead continues up the WF Washougal River but snorkel survey data suggest steelhead do not move past mouth of WF Washougal River in mainstem. The Washougal Salmon Hatchery releases coho and fall Chinook salmon, which access all areas below Duggan Falls. A hatchery coho program is operated on Little Washougal River. This distribution information was used to develop ratings for this attribute.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations, and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Rationale*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Topographic maps were examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road/boat access and high recreational use (the Washougal River road parallels the river from the mouth to Timber Creek a similar road network exists on the Little Washougal River); a rating of 3 was given to areas with road/boat access and proximity to population center and moderate use; 2 was given to reaches with multiple access points ( WF Washougal River) through public lands or unrestricted access through private lands; 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands ( tributaries like Stebbins Creek); 0 was given to reaches with no roads and that are far from population centers (roadless areas above Silver Creek) .

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species is unknown in these watersheds. Predation risks increase on Washougal River below the hatcheries, and below the

Coho salmon release site in the Little Washougal River. Predation risks increased due to introduced fish moving up from Columbia River.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and coho, but no chum were given a rating of 2. Reaches with only coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches). On Washougal River chum dropped out the Little Washougal, Chinook salmon at Salmon Falls, and coho salmon at Duggan Falls. All salmonids except steelhead dropped out at Duggan Falls. Only steelhead, cutthroat trout, scuplins and lamprey accessed reaches above Duggan Falls.

Due to reduced abundance of salmon, the salmon carcass attribute was reduced. Since current escapement estimates for salmon occur in only index areas current estimates of carcass were based on professional opinion of spawning distribution. Recent nutrient enhancement programs have contributed surplus hatchery carcasses to some stream reaches. The recent programs were not included in the salmon carcass attribute. However, under recovery scenarios, they should be included.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—A few direct measures of benthos diversity for selected sites are available within the LCR from Ecology and OSU. Reference sites in the Wind and Cowlitz Rivers yielded B-IBI ratings between 40 and 43 indicating EDT values of 0.3 to 0.9, which is equivalent to an EDT rating of 0.6. Slightly disturbed Rosgen B Channels in the Cowlitz and Grays had ratings of 0.1 to 1.4, but were very close to the averaged undisturbed rating of 0.6. Therefore, for current Rosgen B-channels we assumed the same rating as historic. For disturbed Rosgen C-channels in the Wind River the EDT benthos rating decreased to 1.5. Disturbed C-channels are likely to be more impacted by human activities due to their character than B-channels and the 1.5 EDT rating was used to describe current C-channels. Lower Cedar Creek has a rating B-IBI score of 2.6 or EDT score of 2.6. This reach is right below a disturbed C-Channel where the riparian encroachment has reduced shade, increased temperature, and nutrient levels (fecal coliform) have increased due to agriculture or septic tanks leaks.

B-IBI scores from the Wind River indicate little degradation for Rosgen B channels. Therefore, the 0.6 reference reach rating for current and historical reaches with confined channels. For C channels ratings were degraded to 1.6 based on Wind River data, which supported that B-IBI scores were reduced in less confined channels. Historical less confined channels in the lower basin were rated at 1, current rating was increased to 2 based on nutrients, water temps and DO.

**Acknowledgements**

This project was funded by the Lower Columbia Fish Recovery Board and Washington Department of Fish and Wildlife. We thank Ecology, UCD, USFS, USGS, and OSU for providing their survey data, especially Brian Bair (USFS), Pat Connolly (USGS), and Shannon Claeson (OSU). We thank the staff at Mobrand Biometric Inc for assistance with the EDT model especially Kevin Malone, Jennifer Garrow, Greg Blair, and Rick Paquette.

# E.10. Salmon Creek

## E.10.1. Summary

This report summarizes the values used in the Ecosystem Diagnosis and Treatment Model (EDT) for Salmon Creek. In this project we rated 108 reaches with 45 environmental attributes per reach for current conditions and another 45 for historical conditions. Almost 10,000 (9,720) ratings were assigned and empirical observations within the reach are not available for all of these ratings and comprised only a small percentage of these ratings. To develop the remaining data we used expansion of empirical observations, derived information, expert opinion, and hypothetical. For example, if a stream width measurement existed for a reach and the reach upstream and downstream had similar characteristics then we used the expansion of empirical information from the middle reach to estimate widths in the downstream and upstream reaches. For the fine sediment attribute we could find no data within these watersheds. However, Rittemueller (1986) established a relationship between road density and fine sediment for Olympic Peninsula streams. We applied this relationship to these watersheds; this is an example of derived information. In some cases such as bed scour we had no data for this basin. However, data is available from the Gobar Creek in the Kalama River and observations have been made in the Wind River. We noted that bed scour is related to gradient, stream width, confinement, and confinement-hydromodification. Based on these observations expert opinion was used to estimate bed scour. For rationale behind the ratings see the text below. For specific reach scale information please see the EDT database for the watershed of interest.

Current EDT estimates can be validated when long-term estimates of wild spawners, hatchery spawners, reproductive success of hatchery spawners, and smolts are available. This information in a long enough time series was not available for Salmon Creek. However, the predicted estimates of smolt production for steelhead and Coho are slightly higher than the observed smolt production estimates (DOE 1989). However, when Coho harvest rates are considered, the predicted and actual estimates converge. Chum salmon were extirpated from these watersheds but current EDT model estimates suggest potential chum may be sustainable. The environmental attributes with the most significant impact on salmon performance include: maximum water temperature, riparian function, sediment, bed scour, peak flows, natural confinement, and stream habitat type.

## E.10.2. Recommendations

1. Adult chum salmon, Chinook salmon, Coho salmon, and steelhead population estimates should be initiated. Smolt trapping should be initiated for Chum, Chinook Coho, steelhead, and cutthroat for 10 years. Adult and juvenile population estimates will allow for more accurate assessments of population status and to determine if subbasin restoration actions are effective.
2. The CPU/CCWQ data suggests that maximum temperatures in the middle mainstem of these watersheds increase rapidly. A temperature monitoring program should be established to assess maximum water temperatures for each watershed used by anadromous fish and to locate stream reaches where rapid increase in temperature occurs. The factors that cause the increased reach temperatures should be examined and actions to correct the increase in maximum temperature should be developed.
3. Riparian function is qualitatively not quantitatively estimated. The EDT model should provide more quantitative guidelines for rating riparian function. If fine scale GIS data can be developed for riparian areas, this would assist in a more accurate rating.

4. Sediment estimates were derived information or expanded information from a few observations. A sediment monitoring program should be developed to assess % fines, embeddedness, and turbidity in reaches used by anadromous fish.
5. Differences existed between field and GIS ratings of natural confinement. SSHIAP database should be field verified.
6. Flow and bed scour are not monitored in these basins and estimates were from derived information. Stream gauges should be re-established in these watersheds and bed scour should be estimated.
7. WDFW habitat surveys in 2003 were opportunistic and not systematic; that is, based on a limited amount of time, we chose to survey representative mainstem reaches and representative tributary reaches in the watershed. In addition, glides and pools were distinguished subjectively and not quantitatively. Comprehensive stream surveys should be conducted in these watersheds to estimate habitat type.

## E.10.3. Attributes

### Hydrologic regime – natural

*Definition*—The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.

*Rationale*—This watershed originates from the east hills of Clark County. The maximum elevation is approximately 2,200 ft, which is well below the elevation of substantial snow accumulation. These elevations are consistent with rainfall-dominated watersheds and are classified as such. This watershed was given an EDT rating of 3 for the historic and current conditions. The exception to this was Curtin Cr, which is a ground-fed system and was given an EDT rating of 0 for the historic and current conditions.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Hydrologic regime – regulated

*Definition*—The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

*Rationale*—Historically, there was no regulation of this watershed. For the current condition we analyzed groundwater and surface water rights. This watershed has a significant amount of groundwater pumped by city and domestic water supply. A total of 168 and 97 surface water rights have been filed for Salmon Creek and Burnt Bridge Creek, respectively. Most are currently not in use (GeoEngineers et al. 2001). Due to intermittent water use and the lack of specific flow measurements, we were unable to estimate changes due to groundwater usage.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

## Flow - change in interannual variability in high flows

*Definition*—The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).

*Rationale*—By definition, the template conditions for this attribute are rated as an EDT value of 2, which describes this attribute rating for watersheds in pristine conditions. For the current condition, direct measures of inter annual high flow variation are not available for this basin. For the Salmon Creek Watershed Assessment, MGS Engineering (PGG et al. 2002) used HSPF, a precipitation-runoff computer-modeling program (Bicknell et al. 1997), to estimate the effects of land-use changes on peak flow. The model assumed that 100% of the watershed was forested during pre-settlement because the location and size of prairies could not be reconstructed from the meager evidence. Results of the modeling indicate that total runoff (storm runoff plus base-flow) in the Salmon creek watershed has increased by about 3 in/yr, or about 11 percent, from pre-settlement to the present (PGG et al. 2002). Flood frequency analyses with the HSPF model indicate that 10-year peak discharge rates have increased since pre-settlement by 12 to 28 percent on the mainstem and by 37% to over 245% on tributaries (PGG et al. 2002). The results are shown in Table E7-51. The remaining tributary and mainstem reaches were then feathered and/or given an EDT value of 2.3 where no data exists.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

**Table E7-51. HSPF modeling analyses Q10 year % increases for Salmon Creek Subwatersheds and EDT ratings.**

| Subwatershed | Q10yr % increase | EDT Rating |
|---|---|---|
| Morgan Creek | 37% | 3.3 |
| Woodin Creek | 115% | 4.0 |
| Curtin Creek | 63% | 3.7 |
| Mill Creek | 79% | 3.8 |
| Cougar Creek | 245% | 4.0 |
| Upper Salmon Creek | 12% | 2.3 |
| Salmon Creek @ Northcutt | 25% | 2.7 |
| Salmon Creek @ Klineline | 27% | 2.8 |
| Salmon Creek @ Mouth | 19% | 2.5 |

## Flow - changes in interannual variability in low flows

*Definition*—The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.

*Rationale*—By definition the template conditions for this attribute are rated as a value of two because this describes this attribute rating for watersheds in pristine conditions.

A total of 168 and 97 surface water rights have been filed for Salmon Creek and Burnt Bridge Creek, respectively. Most are currently not in use (GeoEngineers 2001). Due to intermittent water use and the lack of specific flow measurements, we were unable to estimate changes in summer low flow. They probably are occurring at some level.

MGS Engineering estimated reductions in flow using the HSPF model in the Salmon Creek watershed. Low flow EDT ratings were then developed by converting categorical ratings to non-categorical ratings by interpolation. EDT ratings ranged from 2.0 to 3.2. Suds, LaLonde, Tenney Creeks and RBtrib1 received the 2.3 rating from Curtin Creek due to high levels of impervious area and residential development in these subwatersheds. Research on the effects of land use practices on summer low flow is inconclusive. Therefore, we rated the current conditions for all other tributaries the same as template conditions (EDT rating of 2). Table E7-52 shows the results of the model and associated EDT ratings.

**Table E7-52. MGS Engineering HSPF model results showing 7-day low flow statistics at locations in the Salmon Creek Watershed**

| Location | % Change | EDT Rating |
|---|---|---|
| Salmon Creek Nr Battle Ground, Gage S01 | 0.00% | 2.0 |
| Salmon Creek NE 156th St. Gage S04 | 1.04% | 2.0 |
| Salmon Creek Northcutt, Gage S08 | 3.33% | 2.1 |
| Salmon Creek Klineline, Gage S10 | 4.46% | 2.1 |
| Salmon Creek at mouth | 4.19% | 2.1 |
| Morgan Cr | 0.00% | 2.0 |
| Woodin Cr | 0.00% | 2.0 |
| Curtin Cr | 12.50% | 2.3 |
| Lower Mill Cr | 5.00% | 2.1 |
| Cougar Cr | 40.00% | 3.2 |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow – intra daily (diel) variation

*Definition*—Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. For current conditions, we used the percent impervious surface area in major subwatersheds (PGG et al. 2002) to estimate changes in diel flow using the % impervious surface ratings in the EDT stream reach editor. Diel EDT ratings were then developed by converting categorical ratings to non-categorical ratings by interpolation using % total impervious area. Reaches had ratings from 0.2 to 2.3. Table E7-53 shows relationship of EDT reaches with PGG's subwatersheds and their corresponding total impervious areas (%) and EDT ratings.

**Table E7-53. PGG Subwatersheds and associated EDT reaches showing total impervious area (% of basin) and EDT current diel variation ratings.**

| Subwatershed | EDT Reaches | Total Impervious Area (% of Basin) | Diel EDT Rating |
|---|---|---|---|
| 119th Tributary (LaLonde) | Lalonde1 & 2 | 21.00% | 1.2 |
| Cougar Creek | CougarCanyon1 & 2 | 37.40% | 2.3 |
| Curtin Creek | Curtin1 & 2 | 16.90% | 0.9 |
| Morgan Creek | BakerCr1-3, LBtrib2 & 4, RBtrib7, Morgan1-4, and Mud1 & 2 | 8.30% | 0.4 |
| Rock Creek (West) | Rock1-8, LBtrib5, 6, 7-1, 7-2, 8-1, 8-2, and 9 | 4.70% | 0.2 |
| South Mill Creek | Mill1-5, RBtrib2-1, 2-2, 3 and 4 | 9.60% | 0.5 |
| Suds Creek | Suds1-6 | 37.10% | 2.3 |
| Tenny Creek | Tenney Cr. | 31.00% | 1.9 |
| Upper Salmon Creek | Salmon28-32, LBtrib11-1, 11-2, RBtrib11-1, 11-2, 12-1, 12-2, 13 &14, and LittleSalmon1 & 2 | 3.70% | 0.2 |
| Woodin Creek | Weaver1-3, RBtrib5, 6, 8, 9-1 & 2, and 10 | 15.30% | 0.8 |
| Lower Salmon | Salmon1-17, RBtrib1, Klineline1 and KlinelineChannel | 23.41% | 1.4 |
| Mid Salmon | Salmon18-27 | 10.75% | 0.5 |

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Derived information was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Flow –Intra annual flow pattern

*Definition*—The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions. Similar to high flows, monthly and seasonal flow patterns have been affected by land use practices in this watershed. Since there was no data for this attribute, it was suggested that its rating should be similar to that for changes in inter-variability in high flows (pers. com. Larry Lestelle, Mobrand Biometrics, Inc). The EDT ratings for intra-annual flow were applied the same values as the attribute: Flow - change in interannual variability in high flows.

*Level of Proof*—Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established. Expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel length

*Definition*—Length of the primary channel contained within the stream reach -- Note: this attribute will not be given by a category but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.

*Rationale*—The length of each reach was provided by Ned Pittman (WDFW) from SSHIAP GIS layers. We assumed the stream length was the same in both the historical and current conditions.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Channel width – month minimum width

*Definition*—Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—We assigned the same value for both the current and historical conditions, unless a major hydromodification within the reach affects stream width. Representative reaches in Salmon Cr were surveyed in 2003 (WDFW unpublished), and by in the summer of 2001 (Fishman Environmental, unpublished). Wetted widths corresponding to average summer low flows (August) were measured as part of these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reaches with similar habitat, gradient and confinement. The following rules were developed for use in EDT in the Lower Columbia and used in this analysis (WDFW unplublished). For reaches above a split (confluence of 2 tributaries), wetted width was calculated by: {(1.5*downstream reach width)*0.5} for even splits. For uneven splits, the multiplier was adjusted to compensate. In a 60:40 split: (1.5*drw)*0.6 and (1.5*drw)*0.4; and for a 70:30 split: (1.25*drw)*0.7 and (1.25*drw)*0.3. These calculations were referred to as the “split rule”.

A stream width model was developed by Ned Pittman (WDFW unpublished), which correlated well for smaller tributaries. Widths from this model were applied where there were large gaps in data. Rock, Mill, Morgan, and Mud Creeks all have been observed flowing intermittently or subterranean during summer-time low flow events by the TAG (Wade 2001). The minimum width data collected in the field or extracted from Pittman’s width model, was reduced by 20% to account for this occurrence. The surrounding reaches were then extrapolated from these reduced widths using the split rule.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Channel width – month maximum width

*Definition*—Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

*Rationale*—Representative in the Salmon Creek basin were surveyed by WDFW in 2003 and in 2001 (WDFW ,unpublished, and Fishman Environmental Services, unpublished). Historical reaches were assigned the same value as the current condition for all reaches, unless a major hydromodification within the reach currently affects stream width.

Winter flow widths were not collected as part of these surveys. We compared the percent increase between low and high flow widths to the EDT (SSHIAP) confinement rating for each reach. Regression analysis demonstrated little correlation between confinement rating and percent increase in stream width. Mean increase in stream width was 60% after removing outliers for subterranean flow in the summer and Kalama questionable data. A possible explanation for this relationship is that all unconfined reaches in the dataset are downcut due to lack of large woody debris and hydroconfinement. Therefore, we used a 1.6 multiplier (60% increase) to expand "wetted width-low" values for reaches without high flow data.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but is not fully conclusive. For historical information, we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Gradient

*Definition*—Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.

*Rationale*—The average gradient for each stream reach (expressed as % gradient) was calculated by dividing the change in reach elevation by the reach length and multiplying by 100. Ned Pittman (WDFW) used SHIAP GIS layers to provide the beginning elevation, ending elevation, and length for each EDT reach. Historical gradient was assumed to be the same as current gradient.

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive especially for historical length.

### Confinement – natural

*Definition*—The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankfull channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.

*Rationale*—Representative reaches in the Salmon Creek basin were surveyed by WDFW in 2003. Confinement ratings were estimated during these surveys (WDFW, unpublished). In addition, SSHIAP confinement ratings for the watersheds were consulted. Field surveys noted discrepancies between GIS and field ratings. USGS topography maps were consulted when SSHIAP ratings fell between the 0.5 increments to determine which rating should be applied. In turn, EDT confinement ratings were developed by converting SSHIAP ratings of 1-3 to EDT ratings of 0-4 (Table E7-54):

**Table E7-54. Comparison of EDT and SSHIAP confinement ratings.**

| | | | | | |
|---|---|---|---|---|---|
| SSHIAP | 1 | 1.5 | 2 | 2.5 | 3 |
| EDT | 0 | 1 | 2 | 3 | 4 |

There is likely to be multiple SSHIAP segments per EDT segment, where the average SSHIAP confinement rating is calculated, then converted into EDT ratings

*Level of Proof*—Derived information (GIS) was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Confinement – hydromodifications

*Definition*—The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.

*Rationale*—In the historic condition (prior to manmade structures and activity) reaches were fully connected to the floodplain. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Most hydro-modification consists of roads in the floodplain and diking. We consulted the SSHIAP GIS roads layer, SSHIAP hydromodification layer, SSHIAP digital ortho-photos, USGS maps and used professional judgment to assign EDT ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Habitat Type

*Definition*—*Backwater pools* is the percentage of the wetted channel surface area comprising backwater pools. *Beaver ponds* is the percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat. *Primary pools* is the percentage of the wetted channel surface area comprising pools, excluding beaver ponds. *Pool tailouts* are the percentage of the wetted channel surface area comprising pool tailouts.

*Large cobble/boulder riffles* is the percentage of the wetted channel surface area comprising large cobble/boulder riffles. *Small cobble/gravel riffles* is the percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Glides is the percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habitat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.

*Rationale*—Representative reaches the Salmon Creek basin were surveyed in 2003 (WDFW unpublished). Habitat type composition was measured during these surveys. Ratings for non-surveyed reaches were inferred by applying data from representative reach surveys with similar habitat, gradient and confinement. Lower tidal/slough-like reaches from Salmon10 down were rated as 100% glides.

Klineline ponds are abandoned gravel pits. Salmon14_B is the mainstem avulsed into one of these ponds east of I-5. Klineline1 is a pond, which has an unscreened outlet with connection to the mainstem. Reservoir1 is a pond, which has been excavated out of the main channel on Mill Creek. These three reaches are rated as 100% pool.

2003 habitat surveys primarily followed TFW protocol using EDT's habitat types as guidelines. TFW protocol identifies 5 core habitat types: riffle, pool, sub-surface flow, wetland, and obscured. Everything's a riffle unless proven otherwise, pools must meet minimum surface area and residual pool depth criteria following the techniques described in the manual:

**Table E7-55. TFW minimum pool unit criteria**

| Mean Segment BFW (m) | Minimum Surface Area (m^2) | Minimum Residual Pool Depth (m) |
|---|---|---|
| <2.5 | 0.5 | 0.10 |
| >=2.5 - 5.0 | 1.0 | 0.20 |
| >=5.0 - 10 | 2.0 | 0.25 |
| >=10 - 15 | 3.0 | 0.30 |
| >=15 - 20 | 4.0 | 0.35 |
| >= 20 | 5.0 | 0.40 |

One way to think of a pool is like a slightly tipped teacup. If the water supply were to be 'turned off', then water would remain in the pool. "Pools typically form as a result of scour adjacent to channel obstructions and bank resistance during bankfull flows, or due to impoundment of water behind blockages (Pleuss 1999)" TFW lists 10 pool forming factors and 1 more for other/unknown with descriptions of each.

"The classic riffle definition is a shallow and low gradient area with surface turbulence associated with increased flow velocity over gravel or cobble beds. However, riffle classification also includes deeper areas without surface turbulence such as "glides" and "pocket water" conditions, and higher gradient/turbulence areas such as "cascades" and "rapids" (Pleuss 1999)." EDT identifies glides separately which has proven to be difficult. The pool forming factors from above were used as good distinguishing features between some glides and pools along with following the ODFW habitat survey definition of glides.

The results appeared to make sense due to the fact that the watershed has undergone extensive habitat degradation due to urban sprawl, dairies, logging, recreational and other intrusive activities. Therefore, % habitat types were applied to the entire reach where a survey was conducted and reference reaches or averages were applied to reaches un-surveyed showing similarities in gradient, confinement, and land-use activities. Reaches surveyed include: BakerCr1, Morgan3_B, Morgan4, Rock2 & 3, Salmon12, 17, 18, 24, 26, 30, and Weaver1. Estimated surveys include: CougarCanyon1, Morgan2, and Salmon29. A spreadsheet was developed comparing the results of these surveys. Comparisons were made based on field measured gradients and based on GIS gradients. The results showed better relationships using field measured gradients, averages were generated from these results. Table E7-56 shows reference reach or average of reference reaches expanded into other reaches:

**Table E7-56. Reference reaches used to develop ratings for similar reaches.**

| Reference Reaches | Unsurveyed Reaches |
|---|---|
| Average for tributaries >1% | Tributary reaches >2% & <5% |
| Average of Salmon24,25 & 25,26 | Salmon25 |
| Morgan3_BChnlzd | Tributary reaches >5% |
| Salmon12 | Salmon9, 10, &11 |
| Salmon22 | Mill1 |
| Total Average w/o estimates | Tributary reaches <1% |
| Total Average w/o estimates >1% | Tributary reaches >1% & <2% |
| CougarCanyon1 | CougarCanyon2 |
| Mainstem Average | Salmon13,14_A,16,19-23,27,28,&31 |
| Morgan2 | Mud1 & 2 |
| Morgan3_B(beaver) | Rock1 |

Habitat simplification has resulted from timber harvest activities. These activities have decreased the number and quality of pools. Reduction in wood and hydromodifications are believed to be the primary causes for reduction in primary pools. Historic habitat type composition was estimated by examining percent change in large pool frequency data (Sedell and Everest 1991 - Forest Ecosystem Management July 1992, page V-23), and applying this to current habitat type composition estimates. On Germany Creek, the Elochoman River and the Grays River the frequency of large pools between 1935 and 1992 has decreased by 44%, 84%, and 69%, respectively. However, the frequency of large pools increased on the Wind River, but this is likely due to different survey times. The original surveys were conducted in November and the 1992 surveys were conducted during the summer, when flows are lower and pools more abundant.

In general, we assumed for historical conditions that the percentage of pools was significantly higher than the current percentage. For gradients less than 2%, historical pool habitat was estimated to be 50%, which is similar to pool frequency for good habitat (Petersen et al. 1992). For habitats with gradients 2-5% and greater than 5%, we estimated pool habitat to be 40% and 30%, respectively (WFPB 1994). We assumed that tailouts represent 15-20% of pool habitat, which is the current range from WDFW surveys. Glide habitat decreased as gradient increased (Mobrand 2002). Habitat surveys on the Washougal River demonstrated a strong relationship between gradient and glides and this regression was used to estimate glide habitat, which ranged from 25% at gradients less than 0.5% to 6% for gradients greater then 3%. Riffle habitat was estimated by subtracting the percentage of pool, tailout, and glide habitat from 100%. This yielded a relationship where the percentage of riffle habitat increased with gradient. WDFW field data indicated the percentage of gravel riffle habitat decreased with stream gradient, and cobble/boulder riffle habitat increased with stream gradient; the percentage of gravel riffles compared to the total riffle habitat ranged from over 60% at gradients of less than 1% to 15% at gradients greater than 6%. WDFW surveys indicated backwater and dammed habitat increased as gradient decreased. For historical ratings, unconfined low gradient reaches were assumed to have some of these habitat types, and expert opinion was used to assign ratings.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute. Stream surveys allowed accurate classification of fast water (riffles) and slow water (pools and glides) habitat. However, there was likely inconsistency in distinguishing pools from glides and this is likely to affect Coho production due to this species' extended freshwater rearing and preference for pools. The level of proof for current ratings has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Habitat types – off-channel habitat factor

*Definition*—A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.

*Rationale*—When rivers are unconfined they tend to meander across their floodplains forming wetlands, marshes, and ponds. These are considered off-channel habitat. Confined and moderately confined reaches (Rosgen Aa+, A , B and F channels) typically have little or no off-channel habitat. Off-channel habitat increases in unconfined reaches (Rosgen C and E channels). Norman et al. (1998) indicated the potential for abundant off-channel habitat in the lower East Fork Lewis and currently off channel habitat is abundant below Cougar Creek. Mainstem reaches below Cougar Creek get 50% off-channel habitat. Mainstem reaches between Cougar Creek and Mill Creek get 3% off-channel habitat. Curtin1, Mill1-3, Morgan1-3_A, Mud1, Rock1,2&6, Salmon18-25, Suds1, and Weaver1&2 all receive 1% off-channel habitat. The % off-channel habitat was applied to both current and historic with the exception of Mud1, which did not receive any off-channel habitat for current due to extreme incision.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Obstructions to fish migration

*Definition*— Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).

*Rationale*— WDFW SSHIAP database was used to identify existing barriers within these watersheds. EDT requires that obstructions be rated for species, life stages, effectiveness, and percentage of passage effectiveness. This has not been completed for any barriers. In most where known distribution occurred above barriers, passage was assumed to be 100% for the species and all life stages. Since steelhead, chum salmon, and Chinook salmon are generally mainstem and large tributary spawners, barrier effects on these species are minimal. Coho salmon due to their preference for spawning in small tributaries are impacted by barriers. The ratings should be completed after a barrier analysis.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information we expanded empirical observations and used expert opinion and the level of proof has theoretical support with some evidence from experiments or observations.

### Water withdrawals

*Definition*—The number and relative size of water withdrawals in the stream reach.

*Rationale*—No water withdrawals occurred in the pristine condition. A total of 168 and 97 surface water rights have been filed for Salmon Creek and Burnt Bridge Creek, respectively. Most are currently not in use (GeoEngineers 2001). Salmon Creek flows through residential areas throughout most of its lower reaches. Allocated and illegal water-withdrawals occur throughout the watershed. Entrainment believed to be minimal in most if not all of these withdrawals. Reaches with low gradient, unconfined areas (i.e. farmland) and/or reaches with dwellings built next to the stream were given an EDT rating of 0.1 to account for occasional withdrawals as a placeholder. All other reaches were rated at 0

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Bed scour

*Definition*—Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et al. (1992): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

*Rationale*—No bed scour data was available for these basins. Historic bed scour was rated using the look-up table (pers. com. Dan Rawding, WDFW). This table was modified to incorporate the new EDT revisions for bed scour ratings. The table relates bed scour to confinement, wetted width (high flow), and gradient and assumes scour increases as gradient and confinement increase. Current bed scour ratings were increased by 5% for every 0.1 increase in EDT peak flow rating and 5% for each 1.0 increase in EDT hydroconfinement rating. For the tidal reaches of the mainstem Salmon Creek (Salmon 1-10), bed scour ratings were reduced by 50%.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Icing

*Definition*—Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.

*Rationale*—This watershed is rainfall dominated. Anchor ice and icing events do not occur. EDT ratings of 0 were assigned to all reaches in the historical and current condition.

*Level of Proof*—Empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Riparian Function

*Definition*—A measure of riparian function that has been altered within the reach.

*Rationale*—By definition the template conditions for this attribute are rated as a value of zero because this describes this attribute rating for watersheds in pristine conditions. The following rules were developed for use with EDT analysis in the Lower Columbia. These rules were used as guidelines in rating the Salmon Creek watershed for riparian function in EDT.

Riparian zones with mature conifers are rated at 0.0 - 1.0 depending on floodplain connectivity. Riparian zones with saplings and deciduous trees are rated at 1.5 due to loss of shade and bank stability. Riparian zones with brush and few trees would be rated as 2.0. For an EDT rating to exceed 2.0, residential developments or roads need to be in the riparian zone. Therefore, for current conditions, as long as the riparian area has trees, it should have a score of 2.0 or better.

Most vegetated riparian zones with no hydro-confinement should be rated as a 1.0 - 1.5. When hydro-confinement exists start rating from rules on % hydro-confinement and increase rating based on lack of vegetation. Key reaches were established for current riparian function through out the watershed. Other reaches were referenced to these key reaches to develop a final EDT rating

*Level of Proof*—There is no statistical formula used to estimate riparian function. Therefore, expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Wood

*Definition*—The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition of "large logs" as those > 50 cm diameter at midpoint (Schuett-Hames 1999).

*Rationale*—Density of LWD equals pieces * length/width. Template condition for wood is assumed to be 0 for all reaches. To determine current EDT ratings, WDFW and Fishman habitat survey data (unpublished) were consulted. The Fishman surveys included smaller pieces than the EDT model prefers, so only WDFW data was used to calculate a mean EDT rating of 3 for all reaches surveyed. This mean rating was applied to unsurveyed reaches.

Since Fishman surveys included smaller pieces than the EDT model prefers, no EDT ratings better than the mean of 3 could be used. This is because Fishman's LWD density will include smaller pieces as well, resulting in scores better (lower # rating) than they actually are. Therefore only the two Fishman surveys that scored worse than 3 could be used: Mill4 and Morgan3_B received 4's. WDFW survey scores agreed with Morgan3_B's rating, and Mill4 was given an EDT rating of 4. The WDFW survey EDT scores for LWD ratings are provided in Table E7-57.

**Table E7-57. Salmon Creek watershed wood ratings for EDT reaches from WDFW habitat surveys.**

| EDT reach | EDT Rating |
|---|---|
| Salmon12 | 4 |
| Salmon17,18 | 3 |
| Salmon22 | 3 |
| Salmon24,25 | 2 |
| Salmon25,26 | 1 |
| Salmon29 | 3 |
| Salmon30 | 3 |
| Morgan3_B, Baker | 4 |
| Morgan4 | 3 |
| Rock2 | 3 |
| Rock3 | 4 |
| Weaver1 | 3 |
| Cougar1 | 3 |
| **Mean** | **3.0** |

Surveys overlapped EDT sections on four locations: Salmon 17, 18, Salmon24, 25, Salmon25,26, and Morgan 3_B,Baker. Ratings were applied to both reaches. Salmon 25 was given the lowest EDT rating of 2.

## Fine Sediment

*Definition*—Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.

*Rationale*—In the template (pristine) condition, SW Washington watersheds were assumed to have been 6%-11% fines (Peterson et. al. 1992) and EDT rating of 1. Tidal reaches with slowed flows were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 3. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1. Due to the lower gradient of this subbasin, it was thought that percentage fines was historically higher than Petersen et al.(1992) and we used values of 1.3 for most of the watershed and 3.8 on the lower tidal reaches.

Rittmueller (1986) found as road densities increased by 1 mile per square mile, the % fine sediment in spawning gravels increased by 2.6% in Olympic Peninsula watersheds. To rate % fines in the current condition, a scale was developed relating road density to % fines. Tidal reaches with lower gradients were given an EDT rating of 4. Slough-like reaches above tidal reaches or tidal reaches with increased flow during outgoing tide (i.e. lower Salmon Cr.) were rated as follows: rating from road density scale + 1.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

### Embeddedness

*Definition*—The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.

*Rationale*— Peterson et al. (1992) estimated fines to be 6% to 11% in the template (pristine) condition. Under these same conditions we assumed embeddedness was less than 10%, which corresponds to an EDT rating of 0.5. Tidal reaches with slowed water movement were likely areas of heavy sediment deposition (wetlands) and were given an EDT rating of 2. Reaches above tidal with low gradient and slower flows likely also had increased fine sediment and embeddeness and were given an EDT rating of 1.

Rittmueller (1986) found as road densities increased by 1 mile per square mile, the % fine sediment in spawning gravels increased by 2.6% in Olympic Peninsula watersheds. To rate % fines in the current condition, a scale was developed relating road density to % fines. Using fines as a surrogate for embeddedness, EDT ratings were developed. Tidal reaches with lower gradients and ponds & reservoirs were given an EDT rating of 4.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Turbidity (suspended sediment)

*Definition*—The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: $SEV = a + b(\ln X) + c(\ln Y)$ , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

*Rationale*—Suspended sediment levels in the template (pristine) condition were assumed to be at low levels, even during high flow events. CPU and Clark County have been performing a long term monitoring plan. This plan consists of monthly water quality field measurements using a HACH 2100P turbidimeter and water grabs for laboratory analyses. Somewhere in this process, turbidity data results became inconclusive. Correlations were established at each of the eight monitoring locations between flow (CFS) and the following: field turbidity (NTU), lab turbidity (NTU), total suspended solids (mg/L), and total solids (mg/L). These relationships did not prove to make sense for most streams of the Pacific Northwest. From these relationships, as flow increased, turbidity decreased. The measurements also appeared to be too low for this watershed. This could also be in part due to timing of the water sample grabs. For example, a small rain event in the summer can clean the impervious surfaces but not increase flow very much. The creek can become very turbid at low flows. Or in the case of wintertime flows, water samples can be more diluted due to higher volumes of water after the system has been flushed out.

Based on Rawding's analysis of CPU/CCWQ water quality data, the following ratings were assigned. For gradients less than .5% reaches were given the historical rating of 0.8 and the current rating of 1.2; for gradients greater than or equal to .5% and less than 2% reaches were given the historical rating of 0.5 and the current rating of 1.0; for gradients greater than or equal to 2% reaches were given the historical rating of 0.3 and the current rating of 0.5.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations

## Temperature – daily maximum (by month)

*Definition*—Maximum water temperatures within the stream reach during a month.

*Rationale*—Clark County Water Quality placed continuous temperature loggers in various locations within the Salmon Cr. watershed during the summer of 2002. The loggers were located on Curtin Cr, Mill Cr, Woodin Cr, and the mainstem Salmon Cr at 167th avenue, Caples Road, I205 bridge, and near Rock Cr for the summers of 2000, 2001, and 2002. Temperature loggers for Salmon Cr at Caples Road, I-205 bridge, and near Rock Cr were also in the stream for the summer of 1998. In 2003, Clark Public Utilities, Clark County Water Quality, and Water Resources placed additional temp loggers throughout the watershed. This data was plugged into the EDT temperature calculator (MS Access) provided by Mobrand, Inc. to produce EDT ratings. Table E7-58 displays the resulting EDT ratings:

**Table E7-58. Salmon Creek watershed temperature monitoring locations and EDT ratings generated by the EDT temp max calculator for maximum temperatures.**

| | EDT Ratings | | | | | |
|---|---|---|---|---|---|---|
| **Location** | **Avg.** | **2003** | **2002** | **2001** | **2000** | **1998** |
| Salmon Cr - NW 36th Ave | 3.5 | 3.5 | | | | |
| Cougar Cr - upstream of 119th St | 2.2 | 2.2 | | | | |
| Tenney Cr - 117th St | 1.5 | 1.5 | | | | |
| Salmon Cr - Klineline footbridge | 3.5 | 3.5 | | | | |
| Salmon Cr – Northcutt | 3.5 | | 3.5 | 3.5 | 3.5 | 3.5 |
| Mill Cr - 50' above mouth | 3.4 | 3.5 | 3.3 | 3.4 | 3.2 | N/A |
| Salmon Cr - 50th Ave | 3.5 | 3.5 | | | | |
| Curtin Cr - 139th St. | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | N/A |
| Salmon Cr - 156th St | 3.5 | 3.5 | | | | |
| Woodin Cr – 181st St. | 3.5 | 3.5 | 3.5 | 3.5 | 3.4 | N/A |
| Salmon Cr - Caples Rd. | 3.5 | 3.5 | 1.5 | 3.5 | 3.5 | 3.5 |
| Morgan Cr - 167th Ave | 3.5 | 3.5 | | | | |
| Salmon Cr - 167th Ave. | 3.5 | | 3.5 | 3.5 | 3.1 | N/A |
| Salmon Cr - Risto Rd. | 3.3 | 3.5 | 3.2 | 3.3 | 3.2 | 3.4 |
| Rock Cr - upstream of mouth | 3.5 | 3.5 | | | | |

All locations displayed similar ratings for each year with the exception of Salmon Creek at Caples Road 2002. This logger clearly had a malfunction and the average EDT rating for the previous and current years (3.5) was used. For the other locations the average EDT rating was applied for all years. The EDT ratings generated by the temperature calculator were used for reaches with a temperature logger present, and ratings for other reaches were inferred/extrapolated from these based on proximity and similar gradient, habitat, and confinement. If loggers were mid-reach we used the reading for the entire reach. If loggers were at the end of the reach and evidence from other loggers above indicated there was cooling within the reach (as you move upstream), professional judgment was used to develop an average for the reach. The same logic was applied to reaches w/o loggers located between reaches with loggers – ratings from reaches w/ loggers were "feathered" for reaches in between. Readings from loggers at the end of a reach were used to "drive" the rating for the reach downstream. Monitored reference reaches and extrapolated reaches are summarized in Table E7-59.

**Table E7-59. Monitored reference EDT reaches with associated non-monitored EDT reaches and EDT ratings.**

| Monitored Reference EDT Reaches | EDT Rating | Un-monitored EDT Reaches using reference ratings |
|---|---|---|
| CougarCanyon1 | 2.2 | CougarCanyon2, Suds1-6, LaLonde1&2, |
| Curtin1 | 1.5 | Curtin2 |
| Mill1 | 3.4 | Mill2-5, Reservoir1 |
| Morgan1 | 3.5 | Morgan2-4, SideChannel, BakerCr1&2, Mud1&2 |
| Rock1 | 3.5 | Rock2-4 |
| Weaver1 | 3.5 | Weaver2 |
| Salmon8,17,18,19,21&24 | 3.5 | LakeRiver1-3, Salmon1-7,9-16,20,22,23,25,26 |
| Salmon27 | 3.3 | Salmon 28&29 |

*Assumed all small tributaries upstream of Mill Cr (RBtrib2-14, LBtrib2 & 4-11, BakerCr3, Weaver3, Rock5-8) to be rated at 2.5. RBtrib1 rated the same as Salmon Creek (3.5). Salmon 30 (3.0), 31 & 32 (2.5) feathered from Salmon27 (3.3).

On August 30, 2003, WDFW personnel conducted a temperature profile in the watershed.

Table E7-60 shows the temperatures that were recorded:

**Table E7-60. Temperature profile conducted by WDFW in Salmon Creek Watershed on August 30, 2003.**

| Location | Morning Temp. □C | Evening Temp. □C |
|---|---|---|
| Salmon Cr @ 36th Ave (near mouth) | 18.61 | 21.94 |
| Cougar Cr @ 119th St | 14.44 | 16.53 |
| Salmon Cr @ Northcutt | 16.39 | 20.14 |
| Mill Cr @ Salmon Cr Ave | 15.14 | 17.92 |
| Salmon Cr @ 50th Ave | 16.39 | 18.33 |
| Curtin Cr @ 139th St | 12.50 | 14.58 |
| *Salmon Cr @ 158th St | 16.94 | 20.00 |
| Salmon Cr @ 112th Ave | 16.39 | 19.44 |
| *Woodin Cr @ Caples Rd | 15.56 | 20.42 |
| Salmon Cr @ Caples Rd | 16.39 | 19.58 |
| *Salmon Cr @ 142nd Ave | N/A | 21.39 |
| Morgan Cr @ 167th Ave | 15.28 | 19.72 |
| Salmon Cr @ 167th Ave | 17.22 | 20.83 |
| Salmon Cr @ Risto Rd1 | 14.17 | 18.33 |
| *Rock Cr @ 224th St | 15.14 | 18.61 |
| Salmon Cr @ Risto Rd2 | 14.17 | 17.92 |
| Salmon Cr @ 199th St (headwaters) | 14.17 | 17.08 |

* = Questionable Data due to poor representation of temperature from glide or pool habitat or subterranean flow
Tributaries =

Results from the profile displayed a normal decline in temperature moving upstream on the mainstem from 36th avenue to 50th avenue. Then in the upper mainstem, temperatures increasingly got higher between 50th avenue and 167th avenue. This is not normal for a watershed in the Pacific Northwest. Solar input from lack of riparian vegetation (especially on the south bank) on the mainstem above 167th avenue appears to be responsible for these conditions. The input of cooler water from tributaries cools off the mainstem, although EDT ratings remain the same or similar.

Historical temperatures are unknown the in the Salmon Creek subbasin. The Regional Ecosystem Assessment Project estimated the range of historical maximum daily stream temperatures for the Hood/Wind at 7-20 degrees C (USFS 1993). However, this broad range was not very informative for historical individual reach scale temperatures. The only historical temperature data that we located were temperatures recorded in the 1930's and 40's while biologists inventoried salmon abundance and distribution (WDF 1951). Since this data consisted of spot measurements and many basins had been altered by human activity, it was not useful in estimating maximum water temperatures. Stream temperature generally tends to increase in the downstream direction from headwaters to the lowlands because air temperature tends to increase with decreasing elevation, groundwater flow compared to river volume decreases with elevation, and the stream channel widens decreasing the effect of riparian shade as elevation decreases (Sullivan et al. 1990).

To estimate historical maximum temperature, human activities that effect thermal energy transfer to the stream were examined. Six primary process transfer energy to streams and rivers: 1) solar radiation, 2) radiation exchange with the vegetation, 3) convection with the air, 4) evaporation, 5) conduction to the soil, and 6) advection from incoming sources (Sullivan et al. 1990). The four primary environmental variables that regulate heat input and output are: riparian canopy, stream depth, local air temperature, and ground water inflow. Historical riparian conditions along most stream environments in the Lower Columbia River domain consisted of old growth forests. Currently most riparian areas are dominated by immature forest in the lower portions of many rivers. Trees in the riparian zone have been removed for agriculture, and residential or industrial development (Wade 2002). Therefore, on average historical maximum temperatures should be lower than current temperatures.

A temperature model developed by Sullivan et al (1990) assumed there is a relationship between elevation, percentage of shade and the maximum daily stream temperature. This model was further described in the water quality appendix of the current Washington State watershed analysis manual (WFPB 1997). Elevation of stream reaches is estimated from USGS maps. The sky view percentage is the fraction of the total hemispherical view from the center of the stream channel. To estimate the sky view we used the estimated maximum width and assumed that trees in the riparian zone were present an average of 5 meters back from the maximum wetted width. Next we assumed that the riparian zone would consist of old growth cedar, hemlock, Douglas Fir, and Sitka spruce. Mature heights of these trees are estimated to be between 40 – 50 meters for cedar and 60 - 80 meters for Douglas fir (Pojar and MacKinnon 1994). For modeling, we used 49 meters as the average riparian tree height within the western hemlock zone and a canopy density of 85% was assumed (Pelletier 2002). The combination of the height of the bank and average effective tree height was approximately 40 meters for old growth reaches. A relationship was developed between forest shade angle and bankfull width. To estimate the percentage of shade, we used the relationship between forest angle and percentage of shade (WFPB 1997 Appendix G-33.). Finally we used the relationship between elevation, percentage of shade and the maximum daily stream temperature to estimate the maximum temperature (Sullivan et al. 1990, page 204 Figure 7.9). This information was used to establish the base for maximum historical water temperature. These were converted to EDT ratings based on a regression of EDT ratings to maximum temperatures.

The percentage shade from old growth forests in Oregon was estimated to be 84% (Summers 1983) and 80% to 90% in western Washington (Brazier and Brown 1973). For small streams our estimates of stream shade were similar. In comparison to Pelletier (2002), our historical temperatures were slightly lower in small tributaries and slightly higher in the lower mainstem reaches. We developed a correction factor for small tributaries, which consisted of adding 0.3 to the estimated historical EDT rating. These differences are not unexpected, since our simplistic temperature model used only elevation/air temperature and shade, while Pelletier (2002) used QUAL2K, which includes other parameters. We recommend more sophisticated temperature models be used in future analysis because they more accurately estimate temperatures. However, due to limited resources available for this study, the shade/elevation model was used for consistency throughout the Lower Columbia River.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive.

### Temperature – daily minimum (by month)

*Definition*—Minimum water temperatures within the stream reach during a month.

*Rationale*—Pacific Groundwater Group (PGG) has maintained a spreadsheet containing all water quality data for Salmon Creek performed by Clark Public Utilities (CPU), Clark County Water Quality (CCWQ), and Washington Department of Ecology (WDOE) from October 1988 through June 2003. The data has been collected by monthly grab samples resulting in an incomplete data set for wintertime temperatures. Ten years were captured on Cougar, Mill, Curtin, and Woodin Cr, whereas eleven years were captured on the mainstem monitoring locations. January of 1997 was the coldest month recorded throughout the watershed. The number of samples below 4° C for the month of January for all years collected are presented in Table E7-61.

**Table E7-61. Water Quality monitoring grab locations for Salmon Creek with number of samples under 4° C for January and associated EDT reaches (1998-2002).**

| Location | EDT Reach | Lowest Temp °C | # samples under 4°C |
|---|---|---|---|
| Cougar Cr | CougarCanyon1 | 4.2 | 0 |
| Mill Cr | Mill1 | 1.5 | 3 |
| Curtin Cr | Curtin1 | 5.3 | 0 |
| Woodin Cr | Weaver1 | 3.6° | 1 |
| Salmon Cr @ $36^{th}$ Ave | Salmon8 | 2.8° | 1 |
| Salmon Cr above Mill Cr | Salmon18 | 2.5° | 1 |
| Salmon Cr above Woodin Cr | Salmon21 | 2.2° | 1 |
| Salmon Cr @ $199^{th}$ St | Salmon30 | 3.6° | 1 |

In addition, grab data for the current water year was analyzed with the following <4° temperature results. Table E7-62 summarizes the results.

**Table E7-62. Water Quality monitoring grab locations for Salmon Creek with temperatures less than 4° C and associated EDT reaches.**

| Location | EDT Reach | Date | Time | Temp (C) |
|---|---|---|---|---|
| Woodin Cr at Caples Road | Weaver1 | 12/09/02 | 11:43 | 2.0 |
| Mill Cr at Salmon Creek Avenue | Mill1 | 12/09/02 | 10:47 | 3.6 |
| Salmon Cr at NW 36th Avenue | Salmon8 | 12/09/02 | 10:30 | 3.8 |
| Salmon Cr at NE 50th Avenue | Salmon18 | 12/09/02 | 11:00 | 3.0 |
| Salmon Cr at Caples Road | Salmon21 | 12/09/02 | 11:34 | 2.2 |
| Salmon Cr at NE 199th Street | Salmon30 | 12/09/02 | 12:22 | 3.4 |

Two other stations were monitored for temperature throughout the cold months for the winter of 2002-2003. Table E7-63 summarizes the number of days under 4° C.

**Table E7-63. Two Water Quality monitoring grab locations for Salmon Creek with number of days less than 4° C for the winter months of 2002-2003 and associated EDT reaches.**

| Location | EDT Reach | Month | # Days under 4°C |
|---|---|---|---|
| Salmon Cr @ Klineline Footbridge | Salmon13 | November | 2 |
| Salmon Cr @ Klineline Footbridge | Salmon13 | December | 3 |
| Salmon Cr @ Klineline Footbridge | Salmon13 | January | 2 |
| Salmon Cr @ 156th Street | Salmon19 | November | 11 |
| Salmon Cr @ 156th Street | Salmon19 | December | 10 |
| Salmon Cr @ 156th Street | Salmon19 | January | 2 |

Salmon Creek @ $156^{th}$ Street displays questionable data. The habitat there has been altered, resulting in a long, slow-moving glide. This may have some effect on temperature, as well as the location of the temperature monitor. All the above mentioned reaches (Salmon8,13,18,19,21&30, Mill1, CougarCanyon1, Curtin1, and Weaver1) will be given an EDT rating of 1 for the current condition with the exceptions of Cougar Cr and Curtin Cr.

The data could not be plugged into the EDT Temp Calculator, so categorical conclusions were made based on available data. The historic minimum temperature was assumed to be unimpaired thus resulting with the coldest day >4 deg C.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. Expert opinion was used to estimate historic ratings.

### Temperature – spatial variation

*Definition*—The extent of water temperature variation within the reach as influenced by inputs of groundwater.

*Rationale*—Historically there was likely significant groundwater input in low gradient, unconfined to moderately confined reaches of lower watersheds. Presently, it is believed that the number of impervious areas has reduced groundwater recharge and decreased groundwater input.

Higher gradient reaches of the mainstem and tributaries higher in the watershed likely had less groundwater input. These reaches were likely similar to the historic condition and were given an EDT rating of 2 for the current condition. In the current condition, groundwater input in low gradient, unconfined to moderately confined reaches low in the watershed has likely been reduced by current land use practices. These reaches were given an EDT rating of 2 for the current condition. The temperature regime of Curtin Cr has obviously shown the effects of groundwater input, by maintaining more constant temperatures throughout the year. Vegetation has also been observed which indicates upwelling. It is clearly evident that this stream is pre-dominantly groundwater fed and was given an EDT rating of 0.

For the historical condition, reaches with gradients less than 2% and an EDT confinement rating of 2 or less were given an EDT rating of 1 for Temperature-Spatial Variation. The exception to this was Salmon14_C, which has a derived GIS gradient of 2.03%. Historically, this reach was in a lower undisturbed gradient class, and it was also given an EDT rating of 1.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

### Alkalinity

*Definition*—Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.

*Rationale*— Conductivity was calculated using the formula: Alkalinity =0.421*Conductivity – 2.31 from Ptolemy (1993). Conductance values were provided by Clark Public Utilities who recorded monthly grabs by using a Hatch Field Test Kit and/or by taking water samples back to the lab for analysis. EDT values ranged from 1.7 – 3.0 throughout the watershed. The mainstem ranged from 1.7 in the headwaters (Salmon30, @199$^{th}$ St) to 2.7 in the lower watershed (Salmon8, @ 36$^{th}$ Ave) near tidal influence. Cougar Creek at 119$^{th}$ street displayed a moderate flow average alkalinity value of 94.2 mg/L, which corresponded to the high EDT rating of 3.0. Values were applied to entire subwatersheds that include the monitoring grab locations. For example, if Mill1 was monitored, all reaches in the Mill Creek subwatershed (Mill1-5, RBtrib2-1, 2-2, and 3) were given the value of Mill1. Alkalinity in the historic condition was given the same value as the current condition. Table E7-64 summarizes the alkalinity analysis results for CPU monitoring grabs:

**Table E7-64. Alkalinity analysis results for CPU monitoring grabs during 2000-2002 moderate flows.**

| Site | EDT reach | EDT Rating | Cond. µs | Alkalinity mg/L |
|---|---|---|---|---|
| Site 1: Salmon Cr. @ NW 36th Ave. | Salmon8 | 2.7 | 157.47 | 63.99 |
| Site 2: Cougar Creek | CougarCanyon1 | 3 | 229.26 | 94.21 |
| Site 3: Mill Creek | Mill1 | 2.7 | 159.04 | 64.65 |
| Site 4: Salmon Cr. above Mill Cr. | Salmon18 | 2.6 | 117.61 | 47.21 |
| Site 5: Curtin Creek | Curtin1 | 2.8 | 187.60 | 76.67 |
| Site 6: Salmon Cr. @ Caples Rd. | Salmon21 | 2.1 | 71.21 | 27.67 |
| Site 7: Woodin Creek | Weaver1 | 2.7 | 159.63 | 64.89 |
| Site 8: Salmon Creek @ NE 199th St. | Salmon30 | 1.7 | 46.56 | 17.29 |

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations.

## Dissolved oxygen

*Definition*—Average dissolved oxygen within the water column for the specified time interval.

*Rationale*—Dissolved oxygen (DO) in the template (historic) condition was assumed to be unimpaired. Data was based on monthly grabs at long-term monitoring stations on Salmon Creek maintained by Clark Public Utilities (CPU), which was compiled into the Salmon Creek Limiting Factors Analysis (LFA). The LFA analysis was conducted based on Washington Conservation Commission (WCC) rating criteria for basin characteristics. "WCC rates DO as 'poor' if the concentration is below 6 mg/L; 'good' if above 8 mg/L and fair for values in-between"…further rating criteria was established providing "poor, fair, good ratings based on the percent of samples that exceeded WCC values. An exceedence of less than 10 percent of the samples is 'good', 10-20 percent is 'fair' and greater than 20 percent was rated as 'poor'". According to the Salmon Creek LFA, all 8 long-term monitoring locations rated 'good', with the exceptions of Curtin Creek and Salmon Creek at 36$^{th}$ Avenue, which both rated 'fair' (HDR 2002). The good ratings correspond with EDT ratings of 0 and the fair ratings correspond with EDT ratings of 1. Calculations were made on quantitative measurements recorded during CPU's monthly grabs.

Curtin Cr showed an average DO level of 7.13 mg/L for August readings in 2001, 2002, and 2003 which results in an EDT rating of .9. This rating was applied to all of Curtin Cr. Mill Cr @ Salmon Cr Avenue showed a DO level of 7.78 mg/L in August, 2002, which corresponds, to an EDT rating of .2. This rating was applied to all of the Mill Creek reaches. Weaver Cr showed an average DO level of 7.95 mg/L for August readings in 2001, 2002, and 2003 which results in an EDT rating of .1. This rating was applied to the first reach (Weaver1) and 0's for the upstream reaches. Salmon Cr @ 36$^{th}$ Avenue (Salmon8) had an average DO level of 6.7 mg/L for August readings in 2001 and 2003 and received an EDT rating of 1.2. Salmon Cr @ Caples Rd (Salmon21) had a DO level of 7.93 mg/L in August, 2002, which results in an EDT rating of .1. The ratings on the mainstem were feathered between a rating of 1.2 at 36$^{th}$ Ave (Salmon8) and .1 at Caples road (Salmon21).

*Level of Proof*— A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. A combination of empirical observations and expert opinion was used to estimate the historical ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. There is more uncertainty in the ratings for reaches with sloughs, than for riverine reaches.

### Metals – in water column

*Definition*—The extent of dissolved heavy metals within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition. Therefore all reaches were given an EDT rating of 0 for current and historical conditions.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because, of the lack of data.

### Metals/Pollutants – in sediments/soils

*Definition*—The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels.

It should be noted that, "Volatile organic compounds (VOCs) have been detected in two monitoring wells in the lower Salmon Creek basin and in the Bennet well, which is immediately down gradient from the Boomsnub Superfund site" (PGG et al.1998). The VOCs found in the two lower monitoring wells were PCE and TCA, chlorinated solvents which are toxic, mobile, and persistent in groundwater. One of these two lower sites also contains relatively high nitrate concentration. "Boomsnub operated as a metal plating facility from 1967 until June 1994 at 7608 NE 47$^{th}$ Avenue. BOC Gases (formerly Airco), located across the street at 4658 NE 78$^{th}$ Street, is an active compressed gas manufacturing plan. For the purpose of environmental investigation, Boomsnub and BOC Gases are considered as one site because migrating contamination from both facilities has resulted in a merged plume of contaminated groundwater consisting of VOCs and chromium." (PGG et al. 1998) In 1994, the Boomsnub building was demolished and over 6,000 tons of chromium-contaminated soil was removed. Since 1990, a pump-and-treat system has been operating to contain the VOC and chromium plume in the Pleistocene Alluvial aquifer.

Although there is a plume of contaminated groundwater, the effects to the Salmon Creek stream system is unknown, therefore, current levels are unknown and were assumed to be the same as the template condition. All reaches were given an EDT rating of 0 for current and historical conditions.

*Level of Proof*—A combination of derived information and expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Miscellaneous toxic pollutants – water column

*Definition*—The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.

*Rationale*—Historically (template condition), toxic chemicals and metals in the water column and/or sediment were assumed to be non-existent or at background levels. Current levels are unknown and were assumed to be the same as the template condition. Therefore all reaches were given an EDT rating of 0 for current and historical conditions.

*Level of Proof*—Expert opinion was used to estimate the current and historical ratings for this attribute and the level of proof is speculative with little empirical support because of the lack of data.

### Nutrient enrichment

*Definition*—The extent of nutrient enrichment (most often by either nitrogen or phosphorous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids. Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occur in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.

*Rationale*—Actual data for this attribute is very limited.  Historically nutrient enrichment did not occur because watersheds were in the "pristine" state.  Lack of EDT quantifiable data (Chlorophyll a levels) forced assumptions to be made.  An EDT rating of 1 is applied to all reaches with the exception of reaches showing high gradients and/or are surrounded by forested, rural land, which receive a 0.  An EDT rating of 2 is applied to Morgan3_A, RBtrib8, Salmon19, Weaver2, which all have dairy operations or a large number of cows/horses directly in the creek, and to Salmon22 where the Cedars Golf Course is located.

*Level of Proof*—Expert opinion was used to estimate the current ratings for this attribute and the level of proof is speculative with little empirical support because the lack of data.  Empirical observations were used to estimate the historical ratings for this attribute and the level of proof is thoroughly established.

### Fish community richness

*Definition*—Measure of the richness of the fish community (no. of fish taxa, i.e., species).

*Rationale*—Historical fish community richness was estimated from the current distribution of native fish in these watersheds (see below). Reimers and Bond (1967) identify 17 species of fish endemic to the Lower Columbia River and its tributaries, and their current distribution.

Current fish community richness was estimated from direct observation (stream surveys and electro-shocking), personal communications with professional fish biologists familiar with these areas, and local knowledge.  Anadromous fish distribution was estimated from the above as well as from the SSHIAP fish distribution layer & EDT reach descriptions developed by Ned Pittman (WDFW). Data from the following sources were used to better clarify the current fish distribution in Salmon Cr: (1) Screen panel juvenile trap 1.5 km upstream from the mouth of Cougar Cr (Ecology 1989), (2) species present in Hardy Slough (pers. com. Coley, USFWS), (3) Reimers and Bond (1967), and (4) McPheil (1967).

Sixteen incidental fish species trapped at the screen trap include the following: long nose dace, red side shiner, sculpin, northern squawfish, speckled dace, bridge lip sucker, three-spined stickleback, brown bullhead, bluegill, Chinook salmon, pumpkinseed sunfish, pacific lamprey, chiselmouth, mountain whitefish, peamouth, and goldfish (Ecology 1989).

Lower Salmon Creek below Cougar Cr is tidally influenced from the Columbia River backwaters (Ecology 1989) and will likely have many species present from the Lower Columbia River. An estimated 29 species were included in this list: Chinook, chum, Coho, steelhead/rainbow, cutthroat, sculpin sp(3) (torrent, coastrange, reticulate), bridgelip and largescale sucker, peamouth, northern pikeminnow, smelt, sandroller, redside shiner, large & smallmouth bass, carp, goldfish, white & black crappie, eastern banded killifish, yellow perch, sunfish, pumpkinseed, brown & yellow bullhead, white sturgeon, 3-spine stickleback. Most of these fish likely drop out as gradient increases and water temperatures are reduced.

Spot sightings of fish include redside shiner observed throughout Curtin Cr (Manlow 2003), speckled dace found in tributary to Curtin Cr (Dugger 2003), brown bullhead and blue-gill observed in Mill Cr (Weinheimer 2003) and brown bullhead observed in Morgan Cr (Local 2003). Eastern banded killifish, smallmouth bass, bluegill, pumpkinseed, and goldfish were observed (Kelsey 2003) in the back Klineline pond (EDT reach Klineline1) that has direct connection with Salmon Cr (EDT reach Salmon12).

According to SSHIAP's fish distribution layer, Coho, Steelhead and Cutthroat are present throughout the watershed, with only potential distribution on Baker Cr above failed fishway and Little Salmon Cr above culvert. Although steelhead do not penetrate as far as Cutthroat and Coho, distribution ends one EDT reach above where the creeks become to skinny to spawn. Private ponds exist throughout the watershed with potential introductions of pan fish being raised, so one more taxa is added to documented fish.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Fish species introductions

*Definition*—Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.

*Rationale*— By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. Introduced species were derived from current fish species richness data (see Fish Community Richness above). Spot sightings of fish include brown bullhead and blue-gill observed in Mill Cr in 2003 and brown bullhead observed in Morgan Cr ((pers. com. John Weinheimer WDFW). Private ponds exist throughout the watershed with potential introductions of pan fish being raised, so one more taxa is added to documented introductions.

The lower reaches of Salmon Creek likely have many non-native fish from the Lower Columbia River. An estimated 13 species were included in this list: bluegill, large & smallmouth bass, carp, goldfish, white & black crappie, Eastern banded killifish, yellow perch, pumpkinseed, sunfish, brown & yellow bullhead. Most of these fish likely drop out as gradient increases and water cools down. The majority of these species were dropped out on Salmon Cr at Cougar Cr or at the end of tidal influence.

**Table E7-65. EDT ratings for fish species introductions.**

| Section/Species | Rating |
|---|---|
| Curtin Cr=1 species | EDT rating=0.5 |
| Mill Cr=3 species | EDT rating=1.5 |
| Morgan Cr=2 species | EDT rating=1 |
| Upper Mainstem & Rock Cr=1 species; | EDT rating=0.5 |
| Weaver Cr=1 species; | EDT rating=0.5 |
| Other Tribs=1 species | EDT rating=0.5 |
| Mainstem from Morgan – Curtin=2 species | EDT rating=1 |
| Mainstem from Curtin – Mill=3 species; | EDT rating=1.5 |
| Mainstem from Mill – HWY 99 falls=4 species; | EDT rating 1.7 |
| Mainstem from HWY 99 falls – Cougar=5 species; | EDT rating 1.9 |

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

## Hatchery fish outplants

*Definition*—The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.

*Rationale*—By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions. In the historic condition (prior to 1850 and European settlement), there were no hatcheries or hatchery outplants.

Hatchery releases of Chinook, coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2003 and were confirmed with discussions with WDFW staff (Dick Johnson and John Weinheimer) were consulted as well. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency. A WDFW Co-operative project, which reared Coho salmon on Baker Cr., was discontinued in 1996. These reaches were given an EDT rating of 0. Net-pen raised Cutthroat in Klineline pond were discontinued after 1999.

90,000 Coho are raised each year via RSI's in a pond by Curt Anderson's house just below 182nd Ave. An EDT rating of 4 was given to this reach (Salmon25) and below. Net-pen raised Steelhead occur in the Klineline pond planting 20,500 in 2002, and 19,950 in 2003. An EDT rating of 4 was given to reaches below Klineline pond (Salmon13 and down).

One remote site incubator (RSI) has been used on Mill Creek in the past just below the reservoir, but the operator passed away a couple years ago. This creek actually drains into two watersheds: Salmon Creek and East Fork Lewis River. Most of the flow goes to the East Fork whereas habitat and flow are very questionable in reaches below the split heading towards Salmon Creek. WDFW Biologist Weinheimer states he has helped landowners rescue mostly wild origin stranded Coho and released them downstream in the creek to outmigrate through the East Fork Lewis River system with much success on returns. Therefore Mill4 receives a rating of 4 and Mill1-3 received a 4 (2003).

CPU operates 5 RSI's for Coho within the drainage, 10,000 eggs each at the following locations: Curtin1, Meadow Glade 'ditch' upstream of Rbtrib4, Salmon22 @ Brush Prairie, Rbtrib9-1, and LittleSalmon1. These reaches and below were given an EDT rating of 4. Net-pen raised Steelhead occur in the Klineline pond planting 20,500 in 2002, and 19,950 in 2003. An EDT rating of 4 was given to reaches below Klineline pond (Salmon13 and down).

CPU also heads the Salmon in the Classroom program. This program takes aquarium raised Coho (low numbers) and releases them throughout the Salmon Creek and Washougal River watersheds. The number of fish released varies and release sites are concentrated in easy-access park-like locations (pers. comm. Dean Sutherland CPU). One EDT reach above RSI's, access provided, was also rated at 4, and the first reach of tributaries to take into account for the possibility of Coho receiving refuge from high mainstem flows during the winter.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Fish pathogens

*Definition*—The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.

*Rationale*— For this attribute the release of hatchery salmonids is a surrogate for pathogens. In the historic condition there were no hatcheries or hatchery outplants and we assumed an EDT rating of 0. Hatchery releases of Chinook, Coho, steelhead, sea-run cutthroat, and chum were queried from the Columbia River DART (Data Access in Real Time) database (University of Washington, 2003) for the years 1993-2002. A spreadsheet summarizing releases was developed to determine hatchery outplant frequency.

A WDFW co-operative coho program on Baker Cr were discontinued in 1996. These reaches will be given an EDT rating of 0. Approximately 90,000 Coho are raised each year via RSI's in a pond just below 182$^{nd}$ Ave. An EDT rating of 2 was given to this reach (Salmon25) and below. Net-pen raised Steelhead occur in the Klineline pond planting 20,500 in 2002, and 19,950 in 2003. Net-pen raised Cutthroat in Klineline pond were discontinued after 1999. An EDT rating of 2 was given to reaches below Klineline pond (Salmon13 and down). The following table was developed:

**Table E7-66. Coho, Steelhead, and cutthroat releases into Salmon Creek.**

| year | Winter Steelhead | Baker Cr. Coho Salmon | Below 182$^{nd}$ Ave Coho Salmon | Sea-Run Cutthroat |
|---|---|---|---|---|
| 1993 | 18,910 | 200,000 | nd | 10,067 |
| 1994 | 16,962 | 69,509 | nd | 0 |
| 1995 | 15,492 | 13,250 | nd | 10,705 |
| 1996 | 20,200 | 1,725 | nd | 11,020 |
| 1997 | 20,727 | 0 | nd | 12,176 |
| 1998 | 40,895 | 0 | nd | 0 |
| 1999 | 28,011 | 0 | 90,000 | 12,300 |
| 2000 | 20,000 | 0 | 90,000 | 0 |
| 2001 | 0 | 0 | 90,000 | 0 |
| 2002 | 20,500 | 0 | 90,000 | 0 |
| 2003 | 19,950 | 0 | 90,000 | 0 |

CPU operates RSI's for Coho in the following locations: Curtin1, Meadow Glade 'ditch' upstream of Rbtrib4, Salmon22 @ Brush Prairie, Rbtrib9-1, and LittleSalmon1. These reaches and below were given an EDT rating of 2.

One RSI has been used on Mill Creek in the past, but the operator passed away a couple years back just below the reservoir. This creek actually drains into two watersheds: Salmon Creek and East Fork Lewis River. Most of the flow goes to the East Fork whereas habitat and flow are very questionable in reaches below the split heading towards Salmon Creek. WDFW has helped landowners rescue mostly wild origin stranded Coho and released them downstream on the creek to outmigrate through the East Fork Lewis River system with much success on returns. Therefore Mill1-4 received an EDT rating of 2. One EDT reach above RSI's, access provided, and the first reach of tributaries to take into account for the possibility of Coho receiving refuge from high mainstem flows during the winter were also given an EDT rating of 2.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Harassment

*Definition*—The relative extent of poaching and/or harassment of fish within the stream reach.

*Current*—In the historic condition (prior to 1850 and European settlement), harassment levels were assumed to be low. By definition the template conditions for this attribute are rated as a value of 0 because this describes this attribute rating for watersheds in pristine conditions.

Conversations with local fishermen, landowners and biologists were consulted to determine areas of extensive fishing and/or swimming use. County maps were also examined to identify the proximity of stream reaches to population centers, and to estimate access via roads, bridges, gates, boat launches, etc. An EDT rating of 4 was given to reaches with extensive road access and high recreational use (i.e. below the Hwy 99 falls downstream to about ½ mile below Klineline park, Cedar's Golf Course, Woodin Cr through Battleground); an EDT rating of 3 was given to areas with road access and proximity to population center and moderate use (i.e. Salmon Cr above Hwy 99 falls upstream to Mill Cr, Salmon Cr from Woodin Cr to Cedar's Golf Course, Woodin Cr from mouth to Battleground); an EDT rating of 2 was given to reaches with multiple access points (or road parallels reach) through public lands or unrestricted access through private lands (i.e. Salmon Creek through Venersborg and along Risto Road); an EDT rating of 1 was given to reaches with 1 or more access points behind a locked gate or 1 or more access points but limited due to private lands (i.e. Rock Cr); and an EDT rating of 0 was given to reaches with no roads and/or are far from population centers.

*Level of Proof*—There is no statistical formula used to estimate harassment. Therefore, expert opinion was used to estimate the current ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations. For historical information, empirical observations were used to estimate the ratings for this attribute and the level of proof is thoroughly established.

### Predation risk

*Definition*—Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).

*Rationale*—By definition the template conditions for this attribute are rated as a value of 2 because this describes this attribute rating for watersheds in pristine conditions An EDT rating of 3 was given to mainstem reaches below LaLonde Creek, due to influence of Columbia River predators in tidally influenced and low gradient accessible reaches.

The magnitude and timing of yearling hatchery smolt releases, and increases in exotic/native piscivorous fishes were considered when developing this rating. The status of top-level carnivores and other fish eating species is unknown in this watershed. We assumed current predation levels were the same as the template, with the following exceptions: below Salmon11 is assumed to have an EDT rating of 4 due to increase in fish community richness, Mill1-5, Morgan1-3_A, Mud1-2, is assumed to have an EDT rating of 4, and Rock1-7 is assumed to have an EDT rating of 3 due to increased predation due to juvenile trapped in isolated pools.

*Level of Proof*—There is no statistical formula used to estimate predation risk. A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive. For historical information, expansion of empirical observations and expert opinion were used to estimate the ratings for this attribute and the level of proof has theoretical support with some evidence from experiments or observations thoroughly established.

### Salmon Carcasses

*Definition*—Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs. the upper mainstem, or in mainstem areas vs. major tributary drainages.

*Rationale*—Historic carcass abundance was estimated based on the distribution of anadromous fish in the watershed. Reaches with historic chum presence (spawning) were given a rating of 0. Mainstem reaches with Chinook and Coho, but no chum were given a rating of 2. Reaches with only Coho were given a rating of 3. Reaches with only cutthroat or steelhead were given a rating of 4, since these fish do not die after spawning. Tidal reaches below areas of chum spawning were given a 1 (it was assumed carcasses from spawning reaches above are washed into these reaches).

In Salmon Creek, all template carcass information was determined by the above rules. Historically Coho, cutthroat, and steelhead were distributed throughout the entire basin, which received an EDT rating of 3. Chinook spawned from the end of tidal influence (Salmon11) to Mill Cr (Salmon17) and Chum probably dropped out near the HWY 99 falls (Salmon15). Therefore reaches Salmon11 to Salmon14C receive an EDT rating of 0, and Salmon16 & 17 receive and EDT rating of 2. Tidal reaches (Salmon1 – 10) received a 1.

For the current condition, carcass survey data was consulted. Stream surveys conducted annually by WDFW showed very low redd densities for every reach walked. Harvester and Wille conducted redd surveys in 1988-1989 (Ecology 1989), and their counts expanded to less than 25 carcasses per mile. Current surveys support these low numbers. All reaches receive a 4.

*Level of Proof*—A combination of empirical observations, expansion of empirical observations, and expert opinion was used to estimate the current ratings for this attribute and the level of proof has a strong weight of evidence in support but not fully conclusive

### Benthos diversity and production

*Definition*—Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

*Rationale*—FES staff collected benthic macroinvertebrate samples between August 15 and September 10, 2001, at 11 Harvester and Wille (PGG et al. 2002) sites. Macroinvertebrates were sampled and identified using Ecology's Instream Biological Assessment Monitoring Protocols (Plotnikoff, 1994). Aquatic Biology Associates of Corvallis, Oregon, provided taxonomic laboratory services. In addition, data collected in August 1996 by Pratt and others (1998) were reanalyzed for comparison with the 2001 samples (PGG et al. 2002).

Under Ecology's protocols, erosional (riffle) and depositional (pool/glide) habitat units must be sampled separately at each site. However, some sites—one from the 2001 surveys and three from the 1996 surveys—had no riffles. Consequently, only depositional samples were taken (PGG et al. 2002).

A scale was developed for non-categorical EDT rating and Benthic Macroinvertebrate B-IBI scores. Table E7-67 shows the results:

**Table E7-67. B-IBI scores and EDT ratings for EDT reaches in the Salmon Creek watershed.**

| EDT Reach | Habitat Sampled | Year | EDT rating | B-IBI score |
|---|---|---|---|---|
| Salmon8 | pool/glide | 1996 | 3.5 | 10 |
| Salmon18 | riffle | Avg ('96&'01) | 2.5 | 27 |
| Salmon21 | riffle | 1996 | 2.7 | 26 |
| Salmon22 | riffle | 2001 | 2.2 | 30 |
| Salmon25,26 | riffle | 2001 | 2.2 | 30 |
| Salmon30 | riffle | Avg ('96&'01) | 3.0 | 23 |
| CougarCanyon1 | riffle | 1996 | 3.6 | 14 |
| Mill1 | riffle | Avg ('96&'01) | 2.9 | 24 |
| Mill3 | pool/glide | 2001 | 3.0 | 17 |
| Curtin1 | riffle | 2001 | 3.0 | 22 |
| Weaver1 | riffle | 2001 | 2.9 | 24 |
| Morgan2 | riffle | 2001 | 2.0 | 32 |
| Rock2 | riffle | 2001 | 2.4 | 28 |
| LBtrib8-1 (Rock Cr) | riffle | 2001 | 1.1 | 40 |

There were some discrepancies between some of the scores for different years at the same location. An average B-IBI score was applied to come up with an EDT rating.

As the data shows, only two locations in the final ratings were lacking the riffle samples. For all sites where both riffle and pool/glide type habitats were sampled, we compared the difference in EDT ratings. The ratings for pool/glide type habitats averaged 0.4 higher (worse) than the riffle type habitat ratings. Salmon8 and Mill3 were adjusted using this difference resulting in the final EDT ratings shown in the table above. These final EDT ratings were applied to the model and 'feathered' throughout to fill in gaps.

### Acknowledgements

This work was funded as part of subbassin planning. We would like to thank Clark Public Utilities (CPU) staff (Dean Sutherland, Steve Prather, and John Louderbach), Clark County Water Quality staff (Rod Swanson, Jeff Schnabel, and Bob Hutton), Pacific Goundwater Group staff (Dan Matlock and Linton Wildrick), WDFW staff (Ned Pittman, Kathy Armistead-Mai, Carl Dugger, John Weinheimer, Dick Johnson, Stacie Kelsey, Bryce Glaser, Steve Campbell, and Steve Manlow), Fishman Environmental Services (FES), LLC staff (Kathy Armistead-Mai, Steve Novotny, and Kim Gould), and Curt Anderson. The staff at Mobrand Biometrics Inc (Rick Paquette, Jen Garrow, Kevin Malone, and Greg Blair) provided assistance with running the EDT model.

# E.11. References

Anderson, Curt. 2003. Clark County Firefighters Coop. Personal communication.

Bair, Brian. 2003. United States Forest Service. Personal Communication.

Barbour, M.T., J.B. Stribling and J.R. Karr. 1994. Multimetric approach forestablishing biocriteria and measuring biological condition, pp. 63-77 in Davis, W.S. and T.P. Simon (eds), Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, CRC Press, Inc., Boca Raton.

Beak Consultants. 1998. Weyerhaeuser Headquarters Camp Mitigation Project: Surface water and fisheries monitoring trip Sept-Oct 1998.

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigian, A.S., Jr., and Johanson, R.C. 1997. Hydrological Simulation Program—Fortran, User's Manual for Version 11. EPA/600/R-97/080. Athens, GA: U.S. EPA, National Exposure Research Laboratory.

Brazier, J.R., and G.W. Brown. 1973. Buffer strips for stream temperature control. Research paper15. Oregon State University, Forest Research Laboratory, Corvallis.

Byrne, Jim. 2003. Washington Department of Fish & Wildlife. Personal communication.

Canale, G.A. 1999 (draft). BORIS – Benthic evaluation of Oregon rivers. Oregon Department of Environmental Quality, Biomonitoring Section, Laboratory Division. Portland, OR, BIO99-008.

Caromile and Jackson. 2000. Warmwater Fish Survey of Silver Lake, Cowlitz County. Washington Department of Fish and Wildlife.

Coley, Travis. 2003. United States Fish and Wildlife Service. Personal Communication.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. Can. J. Aquat. & Fish. Sci. 59:66-76.

Cowlitz County Public Works Department. 2004. Personal communication.

Dammers, Wolf. 2004. Washington Department of Fish and Wildlife – District Fish Biologist. Personal communication.

Doyle, Eric. 2003. U.R.S. Consulting Firm. Personal Communication.

Dugger, Karl. 2003. Washington Department of Fish & Wildlife. Personal communication.

Duncan, S.H. and J.W. Ward. 1985. The influence of watershed geology and forest roads on the composition of salmon spawning gravel. Northwest Science, Vol. 59, No. 3, 1985.

Ecology, Washington Dept. of, 1989. An Adult and Juvenile Salmonid Population Estimate and Habitat Evaluation in the Salmon Creek Basin. June.

Forest Ecosystem Management: An Ecological , Economic, and Social Assessment; Report of the Forest Ecosystem Management Assessment Team. July 1993.

GeoEngineers, Inc., WEST Consultants, Inc., & Hammond Collier Wade Livingstone. 2001. Level I Technical Assessment for WRIAs 27 & 28 June 29, 2001.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream7 Hydrology: An Introduction for Ecologists. John Wiley & Sons, Ltd., West Sussex, England.

Gross, Steve 2004. Washington Department of Fish & Wildlife. Kalama Falls Hatchery. Personal communication.

Hallock, Molly 2003. Washington Department of Fish & Wildlife. Personal communication.

Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:834-844.

Hanratty, Pat. 2003. Washington Department of Fish & Wildlife. Personal communication.

Hawkins, C.P. and 10 coauthors. 1993. A hierarchical approach to classifying stream habitat features. Fisheries (Bethesda) 18(6): 3-12.

HDR Engineering, Inc. 2002. Salmon Creek Limiting Factors Analysis. Prepared for the U.S. Army Corps of Engineers, Portland District and Clark Public Utilities. June.

Houpt, Darrin; Zoanne Aylesworth; Steve Stinson. 1994. Silver Lake Watershed management plan. Cowlitz County Conservation District. September 1, 1994.

Hyatt, T.L. and R.J. Naiman. 2001. The residence time of large woody debris in the Queets River, Washington, USA. Ecological Applications 11(1) 191-202.

Johnson, Dick. 2003. Hatcheries Manager. Washington Department of Fish & Wildlife. Personal communication.

Karr, J.R. and E.W. Chu. 1999a. Biological monitoring: essential foundation for ecological risk assessment. Human and Ecological Risk Assessment. 3: 933-1004.

Karr, J.R. and E.W. Chu. 1999b. Restoring Life in Running Waters—Better Biological Monitoring. Island Press, Covelo, CA.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessment of biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Kelsey, Stacie. 2003. Washington Department of Fish and Wildlife. Personal communication.

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions American Fisheries Society 129:262-281.

Konrad, C.P. 2000a. The frequency and extent of hydrologic disturbances in streams in the Puget Lowland, Washington. Ph.D Dissertation, University of Washington, Seattle, WA.

Konrad, C.P. 2000b. New metrics to characterize the influence of urban development on stream flow patterns. The Washington Water Resource 11(4):3-6. Available online at http://depts.washington.edu/cuwrm/

Lavier, D.C. 1973. Preliminary Report on Silver Lake Cowlitz County, Washington. Washington Department of Game.

LCFRB. Lower Columbia Fish Recovery Board, 2001. Level 1 Technical Assessment Final Report for WRIAS 25 & 26.

LCFRB. Lower Columbia Fish Recovery Board, 2003. Draft Lower Columbia Recovery Plan Technical Foundation. Revised 8/05/03.

Lestelle, Larry. 2003. Mobrand Biometrics, Inc. Personal communication.

Local landowner. 2003. Local landowner on Morgan Creek. Personal communication.

Loch John. 2000. Washington Department of Fish and Wildlife. Personal communication.

Loch, John. And Paul Downing. 1990. 1989 Toutle River Fish Collection Facility Operation and Salmonid Investigations. Washington Department of Wildlife. Fisheries Management Division. F.M. No. 89-13.

Lunetta, R.S., B.L. Cosentino, D.R. Montgomery, E.M. Beamer, and T.J. Beechie. 1997. *GIS-based evaluation of salmon habitat in the Pacific Northwest.* Photogrammetric Engineering and Remote Sensing 63:1219-1229.

Manlow, Steve. 2003. Regional Habitat Manager. Washington Department of Fish & Wildlife. Personal communication.

May, C.W., E.B. Welch, R.R. Horner, J.R. Karr and B.W. Mar. 1997. Quality indices for urbanization effects in Puget Sound lowland streams. Water Resources Series Technical Report 154, Washington Department of Ecology, Seattle, WA.

McPheil, J.D. 1967. Distribution of Freshwater Fishes in Western Washington. Northwest Science, Vol. 41, No. 1, pp.1-11.

Mebust, David. 2003. Cathlamet Timber Company. Personal Communication.

MGS Engineering and Pacific Groundwater Group, 2002. Hydrologic Analysis of the Salmon Creek Watershed Using the HSPF Model, Olympia, WA for Clark Public Utilities and Clark County Dept. of Public Works.

Miller, Darrin 2003. Washington Department of Fish & Wildlife. Elochoman Hatchery Manager. Personal communication.

Mobrand Biometrics Inc. 2002. Subbasin planning with EDT: A Primer. Mobrand Biometrics Inc. http://www.edthome.org/sbp/SBPandEDT.pdf

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife. Available at: http://oregonstate.edu/Dept/ODFW/freshwater/inventory/pdffiles/habmethod.pdf

Morley, S.A. 2000. Effects of urbanization on the biological integity of Puget Sound lowland streams: Restoration with a biological focus, Washington, USA. Thesis, University of Washington, Seattle, WA.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Norman, DK, CJ, Cederholm, and WS Lingley, Jr. 1998. Flood plains, salmon habitat, and sand and gravel mining. Washington Geology 26: 3-20.

Pelletier, G. 2002. Wind River watershed temperature total maximum daily load. Washington Department of Ecology. http://www.ecy.wa.gov.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions. Report TFW-F3-92-001, Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife, Olympia, WA.

PGG. Pacific Groundwater Group, and Rod Orlando. 1998. Salmon Creek Basin Monitoring and Management Implementation Plan Annual Report, 1997. December.

Pittman, Ned. 2003. Washington Department of Fish & Wildlife. Personal communication.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138; USDA Forest Service, Intermountain Forest and Range Experimental Station, Ogden, UT.

Pleus, A.E., D. Schuett-Hames, and L. Bullchild. 1999. TFW Monitoring Program method manual for the habitat unit survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-003. DNR #105. June.

Plotnikoff, R. W. 1994. Instream Biological Assessment Monitoring Protocols: Benthic Macroinvertebrates. June 1994 Publication #94-113. Environmental Investigations and Laboratory Services Ambient Monitoring Section, Washington State Department of Ecology.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast. Lone Pine Publishing. Vancouver, BC.

Ptolemy, R.A. 1993. Maximum salmonid densities in fluvial habitats in British Columbia. Pages 223-250 i*n* Proceedings of the 1992 Coho Workshop, Association of Professional Biologists of British Columbia and North Pacific International Chapter of the American Fisheries Society.

Rawding, Dan. 2003. Washington Department of Fish & Wildlife. Personal communication.

Reimers, Paul E. and Carl E. Bond. 1967. Distribution of Fishes in Tributaries of the Lower Columbia River. Copeia, no.3, pp.541-550.

Richert, Byron. 2004. Weyerhaeuser Timber Company – Longview, WA. Personal Communication.

Rittmueller, J.F. 1986. Effects of logging roads on the composition of spawning gravel in streams of the west slope Olympic Mountains, Washington. M.S. Thesis, University of Washington, Seattle, WA.

Scherer, N. 1996. Silver Lake Phase II Study, 1995 Annual Report. Prepared for Cowlitz County Department of Community Development by KCM, Inc. Seattle, WA. January 1996.

Schuett-Hames, D., A.E. Pleus, J. Ward. M. Fox, and J. Light. 1999. TFW Monitoring method manual for the large woody debris survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106

Sedell, J.R.; Everest, F.H. 1991. Historic changes in pool habitat for Columbia River Basin Salmon under study for TES listing. Draft report, December 1990. Corvallis, Oregon: USDA Forest Service, Pacific Northwest Research Station.

Seiler, Dave. 2003. Washington Department of Fish & Wildlife. Personal communication.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, P. Knudsen. 1990. Evaluation of predictive models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006. Washington Dept. Nat. Resources, Olympia, WA. 224pp.

Summers, John H. 2001. Salmon Recovery Index Watershed Monitoring Program. Water Quality Index Report, October 2000-2001. Washington Department of Ecology. Publication No. 01-03-046.

Summers, R. 1983. Trends in riparian vegetation regrowth following timber harvest in western Oregon watersheds. M.S. thesis. Oregon State University, Corvallis.

U.S. Geological Survey. 2003. Washington Historical Resources Data (http://wa.water.usgs.gov/realtime/historical.html).

University of Washington. 2003. School of Aquatic & Fishery Sciences, Columbia Basin Research. Columbia River DART (Data Access in Real Time) (http://www.cqs.washington.edu/dart.html)

USFS and 5 coauthors. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment; Report of the Forest Ecosystem Management Assessment Team.

USFS. 1993. U.S. Department of Agriculture, Forest Service. Ecological assessment, a first approximation. Pacific Northwest Region, Portland OR.

USFS. 1995. U.S. Department of Agriculture, Forest Service. Upper East Fork Lewis River Watershed Analysis – Gifford Pinchot National Forest. December 1995.

USFS. 1995b. U.S. Department of Agriculture, Forest Service. Middle and Upper Cispus River Pilot Watershed Analysis – Gifford Pinchot National Forest Randle and Packwood Ranger Districts. June 1995.

USFS. 1996a. U.S. Department of Agriculture, Forest Service. Upper Kalama River Watershed Analysis – Gifford Pinchot National Forest. September 1996.

USFS. 1996b U.S. Department of Agriculture, Forest Service. Lower Lewis River Watershed Analysis – Gifford Pinchot National Forest. July 1996.

USFS. 1997. U.S. Department of Agriculture, Forest Service. Upper Toutle River Watershed Analysis – Gifford Pinchot National Forest. September 1997.

USFS. 2000. U.S. Department of Agriculture, Forest Service. 2000. Rock Creek Watershed Analysis – Gifford Pinchot national Forest Mt. Adams Ranger District. September 2000.

USGS. 2004. U.S. Geological Survey. Washington Historical Resources Data (http://wa.water.usgs.gov/realtime/historical.html).

VanderPloeg, Steven and Julie Grobelny. 2004. Washington Department of Fish and Wildlife. Personal Communication.

VanderPloeg, Steven. 2003. Habitat Surveys. Washington Department of Fish and Wildlife.

Wade, G. 2000. Salmon and steelhead habitat limiting factors: water resource inventory area 26. Washington Conservation Commission, Olympia.

Wade, G. 2000. Salmon and steelhead habitat limiting factors: water resource inventory area 27. Washington Conservation Commission, Olympia.

Wade, Gary. 2001. Salmon and Steelhead Habitat Limiting Factors: Water Resource Inventory Area 28. March 21, 2001.

WDF. 1951. Lower Columbia River Fisheries Development Program. Washington Department of Fisheries. Olympia, WA

Weinheimer, John. 2003. Regional Fish Biologist. Washington Department of Fish & Wildlife. Personal communication.

Weyerhaeuser. 1994. Silver Lake watershed analysis. Prepared for Washington State Department of Natural Resources. Forest Practice Division. February 1994.

WFPB 1994. Standard methodology for conducting watershed analysis. Washington Forest Practices Board. Olympia, WA.

WFPB 1997. Standard methodology for conducting watershed analysis, version 4.0. Washington Forest Practices Board. Olympia, WA.

Zydlewski, Joe. 2003. United States Fish and Wildlife Service. Personal Communication