CHAPTER 3. DERIVED DATA AND SAMPLED PARAMETERS

Terms Used in this Chapter

Accuracy - the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the quality of data and the number of errors contained in a data set or map. In discussing a GIS database, it is possible to consider horizontal and vertical accuracy with respect to geographic position, as well as attribute, conceptual, and logical accuracy.

Automated Sampling – Attributes of spatial data sets are sampled with DEQ software and placed in a database.

Digital Elevation Model (DEM) – A digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. Converting hypsographic and hydrographic tagged vector files produces accurate elevation models.

Digitize – Manually drawing polylines or polygons around features that are visible in rectified in aerial photography. Spatial data sets for land cover, stream position, channel width, etc. can be developed by digitizing these physical attributes.

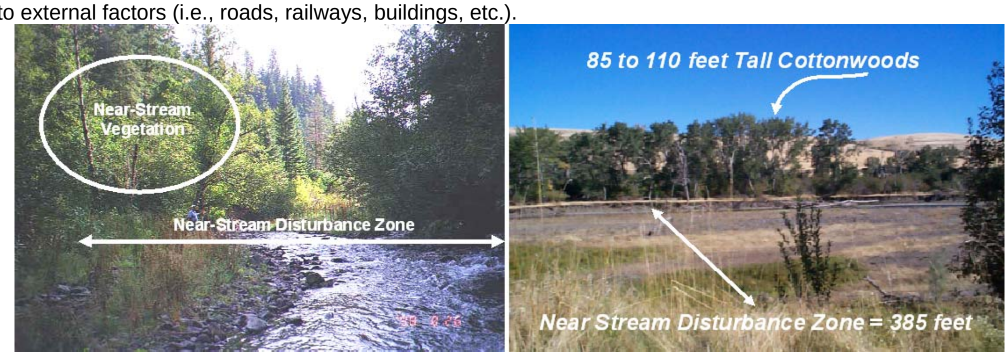
Drainage Area: The upslope area that contributes to flow accumulations above a particular point along a stream. This area is calculated by DEQ at various sites based on hydrography. An ArcView sampling tool delineates drainage area using a 10-meter pixel digital elevation model (DEM) as a base layer.

Gradient – Refers to slope and quantified as rise divided by run.

Landsat Data – Satellite data that can be classified to identify landscape features such as vegetation, roads, buildings, etc.

Mass Balance – A longitudinal profile of flow volume derived by accounting for gains and losses of flow.

Near-Stream Disturbance Zone (NSDZ) - is defined for purposes of the TMDL as the width between shade-producing near-stream vegetation. This dimension was measured from rectified digital aerial photography. Where near-stream vegetation was absent, the near-stream boundary was used, defined as downcut stream banks or where the near-stream zone is unsuitable for vegetation growth due to external factors (i.e., roads, railways, buildings, etc.).



Orthophoto – Aerial photos that have been rectified

Plan View – Looking directly down at the earth surface.

Precision - the level of measurement and exactness of description in a GIS database. Precise locational data may measure position to a fraction of a unit. Precise attribute information may specify the characteristics of features in great detail. It is important to realize, however, that precise data--no matter how carefully measured--may be inaccurate. Surveyors may make mistakes or data may be entered into the database incorrectly.

Rectification – Adjusting for distortions caused by terrain elevation gradients and camera angle to produce map quality photo images.

Regional Curve: Leopold et al. (1964) demonstrated that bankfull channel dimensions tend to increase with increases in drainage area. A power function is commonly used to relate channel dimensions to drainage area plotted on a log-log scale. Regional curves are generally constructed for hydrologic units (i.e. stratified by 5th, 4th or 3rd field HUC codes). Rosgen (1996) recommends an additional stratification by a common stream type for regional curves. "When stratified by stream type, plots of bankfull dimensions prove even more useful for estimating similar channel dimensions for ungaged areas" (Rosgen, 1996). Level I Rosgen channel types are used to stratify the regional curves presented below.

Resolution – Scale for which a spatial data set is accurate

Sinuosity – A quantification of the degree of meander in a stream segment.

Stream Data Node – The points created along the stream centerline at a 100-foot interval used to sample topographic, channel and land cover parameters.

Width to Depth Ratio - Bankfull width divided by bankfull depth.

3.1 Sampled Parameters

Sampling numeric GIS data sets for several landscape parameters and performing simple calculations is done to derive spatial data for several stream parameters. Sampling density is user-defined and generally matches any GIS data resolution and accuracy. The sampled parameters used in the stream temperature analysis are:

- Stream Position and Aspect,
- Stream Elevation and Gradient (stream bed, valley - transverse and longitudinal),
- Maximum Topographic Shade Angles (East, South, West),
- Channel Width,
- FLIR Temperature Data Associations, and
- Near Stream Land Cover.

The following sections of this chapter detail the methodologies, results, resolution and accuracy for each derived data type.

3.2 Resolution - Map Scale & Horizontal Accuracy

Development and refinement of spatial data focuses on achieving the highest resolution (i.e., less than 1:5,000). This includes digitizing high-resolution aerial imagery and checking against ground level data. In many cases land cover can be accurately mapped from existing and publicly available digital orthophotos. Streams and channel edges can also be quickly and accurately mapped to less than 1:5,000 from orthophotos, provided that channel edges are visible in plan view and are several times greater than the photo resolution. In both cases ground level data are used to assess spatial data accuracy.

Ground features are accurate within the limits of the mapping accuracy. Landscape parameters can only be reliably measured when considering the accuracy limitations. Oregon DEQ recommends GIS data mapping scales that target 1:5,000 or less, with the exception of DEMs, where 10-meter pixel data are preferred.

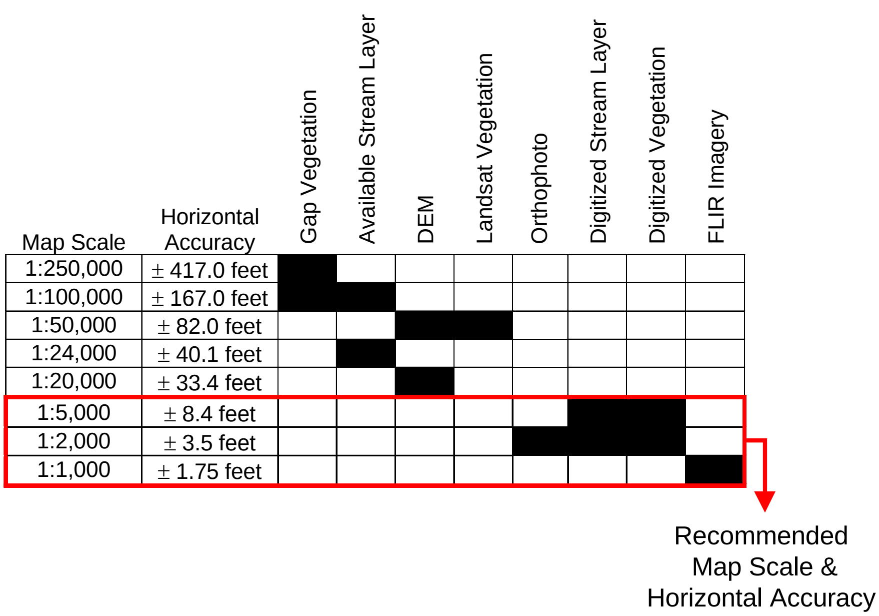


Figure 3-1. *Accuracy Limitations for Different Map Scales*

When sampling spatial data sets it is important to consider the accuracy of the GIS data being sampled. Many data sources/types are available (Stream Layers, Digital Elevation Models, Vegetation Data, etc.); however, much of this data is coarse and may fail to capture spatially variable landscape parameters.

Whenever possible DEQ samples at a high resolution. However, sampling resolution should not exceed the accuracy of the data being sampled.

Stream position is used to develop reference points for sampling. The stream polyline accuracy is a function of the map scale. For example, **Figure 3-2** demonstrates that a stream polyline at 1:100,000 mapping scale (red line) simplifies sinuosity and has local horizontal inaccuracies of over 200 feet. Sampling with a 1:100,000 stream polyline will result in inaccurate sampling reference points and simplified stream sinuosity. As can be seen in **Figure 3-2**, a stream polyline digitized at 1:5,000 mapping scale will properly identify stream position and will yield accurate spatial reference points for sampling of other stream parameters relative to the stream data node.

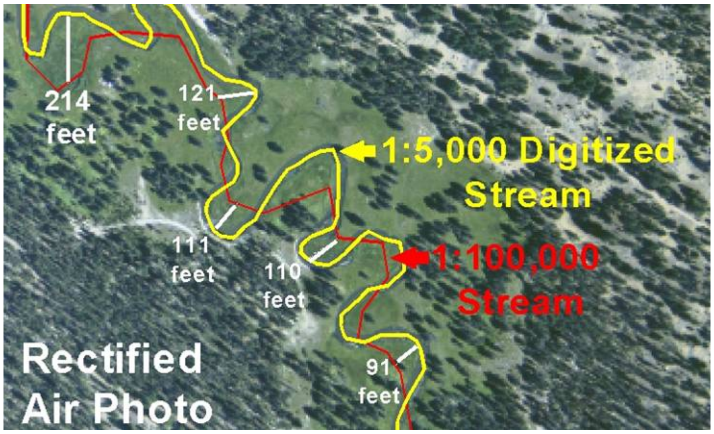


Figure 3-2. *Map Scales Comparing Stream Polyline Accuracy at 1:100,000 and 1:5,000 (Rectified Air Photos are analogous to Digital Orthophotos)*

3.3 Stream Mapping and Segment Data Nodes

Stream position is mapped at 1:5,000 or less using rectified aerial photos and digital orthophoto quads. The centerline of the stream is estimated and digitized as a continuous stream polyline. Where the stream channel is braided, the largest stream channel is digitized. This stream polyline is then segmented into point data nodes at 100-foot intervals. Oregon DEQ has found that a 100-foot longitudinal sampling interval maintains data resolution without creating data sets that overwhelm hardware limitations (i.e., computer memory and CPU time). The resulting segmented point data nodes are used for sampling of the derived data parameters.

3.4 Channel Morphology

3.4.1 Overview

Channel morphology is largely a function of high flow volume magnitude and frequency, stream gradient, sediment supply and transportation, stream bed and bank materials and stream bank stability (Rosgen 1996 and Leopold et al. 1964).

Ground level measured and GIS sampled channel morphology data reveals that some stream reaches in the Nehalem River subbasin have experienced channel widening. These stream reaches were identified by developing linear regression models near stream disturbance zone (NSDZ) width estimates as a function of drainage area. Degraded channel morphology largely results from channelization and/or near stream vegetation disturbance. Due to lack of data the impact of sedimentation on channel morphology is not quantified, however, the typical response is channel widening, amongst other channel responses.

The predominant thermodynamic influence of channel morphology is quite simple. Wider channels result in the combined effect of increased solar radiation loading via decreased stream surface shade and increased stream surface area exposed to solar radiation loading. A wider stream has a larger surface exposed to surface thermal processes. Other thermal effects that relate to channel morphology include altered stream hydraulics caused by increased wetted perimeter and decreased stream depth. Disturbance of surface and groundwater interactions may also result from channel morphology modifications and have the combined effects of lowering near stream groundwater tables, reducing the groundwater inflow, removing cool sources of groundwater that serve to reduce instream temperatures and modifying hyporheic flows. Substrate changes may decrease or impair hyporheic flows (i.e. flows that occur in the interstitial spaces in the bed substrate) that help buffer stream temperature change.

Passive restoration of channel morphology should be a primary focus of temperature related restoration efforts in the North Coast Subbasins. Passive restoration efforts should include: removing sources of channel disturbance that are known to degrade and slow or prevent restoration. Near stream land cover is a primary component in shaping channel form and function and should be a significant emphasis in all restoration planning and activities. Active restoration should be considered where severe channel disturbances cannot be remedied via passive restoration techniques. Examples of areas where active restoration should be considered should include severe vertical down cutting, diked channels and removal of instream structures that prevent progress towards the desired stream channel condition. Other instream structures can serve as beneficial in channel restoration such as rock barbs, sediment catchments, etc.

3.4.2 Assessment Methodology

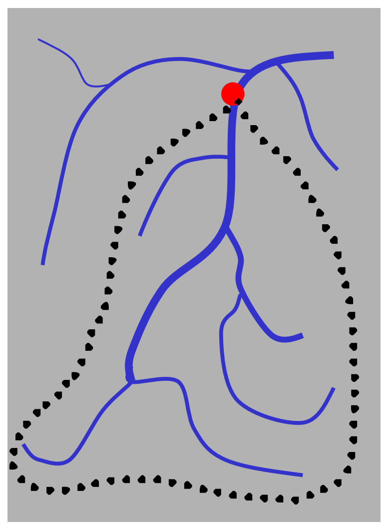
The derived channel morphology data types are described in detail in this section. GIS data sampling is performed with TTools[1]. Derived data sets that relate to channel morphology are developed for the following streams and rivers in the Nehalem River subbasin:

- Nehalem River
- North Fork Nehalem River
- Cook Creek
- Salmonberry River
- Rock Creek

Drainage Area

Drainage area is delineated and measured from a 10-meter digital elevation model (DEM). An ArcView sampling tool delineates the contributing area of the watershed above specified locations along a stream. Surface area within the delineation is calculated in 10-meter pixel units. The stream data nodes are the points of reference for sampling.

Drainage area data are used for regional curve development.

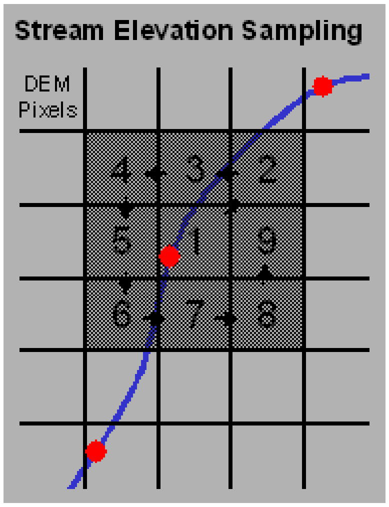


[1] TTools is a sampling extension developed for ArcView. It is used by Oregon DEQ to create spatial data sets for stream networks. DEQ currently maintains the TTools methodology and computer programming. TTools and supporting documentation can be downloading from DEQ at: http://waterquality.deq.state.or.us/wq/TMDLs/WQAnalTools.htm.

Stream Elevation

Stream elevation is measured from a 10-meter digital elevation model (DEM). TTools[5] will auto-detect the pixel size (either 10 meter or 30 meter) of the DEM. In order to find the lowest pixel nearest to the stream segment node, TTools samples nine pixels: the pixel that falls directly on the stream segment node and the eight surrounding pixels. The lowest elevation sampled is assigned to the stream segment node.

Stream elevation data are used to calculate stream gradients.



Stream Gradient

Stream gradient is calculated from the elevation of the stream node and the distance between nodes. The DEMs have a 3.3 feet (one meter) elevation resolution. It commonly occurs that a measurable (i.e., greater than 3.3 feet) elevation drop spans several of the stream segment nodes. Gradients are calculated as:

$$\text{Stream Gradient} = \frac{\text{Change in Stream Elevation}}{\text{Stream Segment Length}} = \frac{\text{Change in Stream Elevation}}{\text{(\# of Stream Nodes)(Segment Interval)}}$$

Stream gradient data are used to:

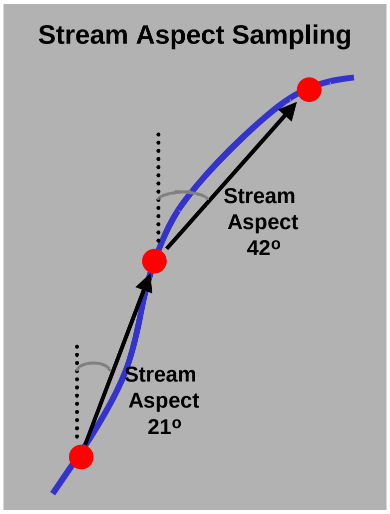
- *Calculate stream velocity with Manning's equation*
- *Classify Rosgen level I stream types.*

Stream Aspect

Stream aspect is calculated as the downstream angle between two stream nodes and north. Units recorded are degrees from north, in the downstream direction.

Stream aspect data are used to:

- *Reference the longitudinal direction and allows the calculation of the transverse direction at each stream data node,*
- *Position the stream relative to simulated surrounding features such as the sun, surrounding near stream land cover and shade producing topographic features.*

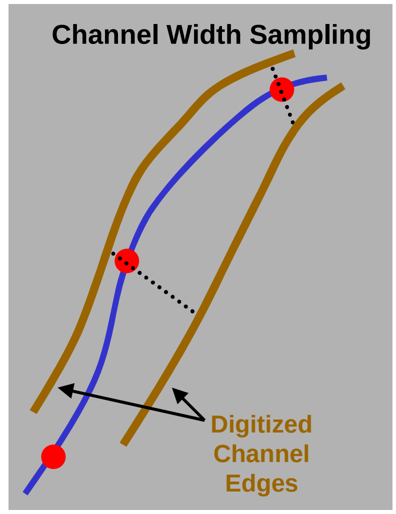


Near Stream Disturbance Zone Width

Near stream disturbance zone width can be measured from digitized channel edge polylines. At each stream segment node, TTools measures the distance between the left and right channel edge polylines in the transverse direction (i.e., perpendicular to the aspect).

Near stream disturbance zone width data are used to:

- *Approximate bankfull width,*
- *Serve as inner boundaries where transverse near stream land cover sampling starts.*



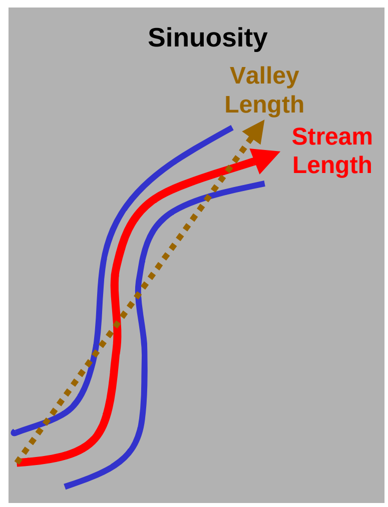
Stream Sinuosity

Stream sinuosity is the stream length to valley length ratio. Sinuosity data are calculated as:

$$\textbf{Stream Sinuosity} = \frac{\textbf{Stream Length}}{\textbf{Valley Length}}$$

Stream sinuosity data are used to:

- *Assess stream condition,*
- *Develop Rosgen level I channel classifications.*



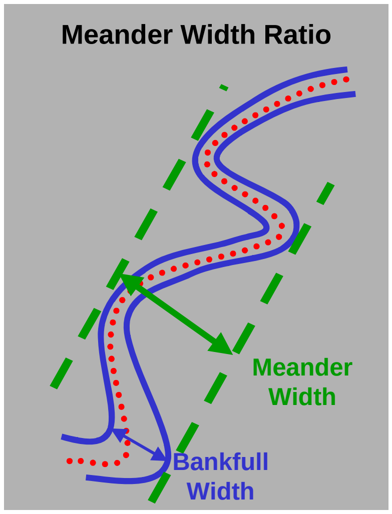
Meander Width Ratio

Meander width ratio is the meander width to bankfull width ratio. Meander width is the belt width or amplitude of the meander geometry.

$$\text{Meander Width Ratio} = \frac{\text{Meander Width}}{\text{Bankfull Width}}$$

Meander width ratio data are used to:

- *Assess stream condition,*
- *Develop Rosgen level I channel classifications*



3.4.3 Stream Gradient, Sinuosity, and Meander Width Ratio

GIS derived stream gradient, sinuosity and meander width ratio data are used to assess stream condition and help classify Rosgen level I stream types. In some cases the Rosgen data ranges are quite broad and staff professional judgments were used to type streams. In general, Rosgen level I stream types can be described as follows:

Type A - High Relief, Erosional/Depositional and Bedrock Features, Entrenched and Confined Streams w/ Cascading Reaches

Type B - Moderate Relief, Moderate Entrenchment and W/D Ratio, Narrow Gently Sloping Valleys, Rapids Predominate w/ Scour Pools

Type C - Broad Valleys w/ Terraces, Associated w/ Floodplains, Alluvial Soils Slightly Entrenched, Well Defined Meandering Channels

Type D - Broad Valleys w/ Alluvium, Steeper Fans, Glacial Debris, Active Lateral Adjustment, Abundant Sediment Supply, Aggradational Processes, High Bedload and Bank Erosion

Type DA - Broad Low Gradient Valleys, Fine Alluvium, Multiple Channels, Laterally Stable w/ Broad Wetland Floodplains, Very Low Bedload, High Wash Load Sediment

Type E - Broad Valley/Meadows, Alluvial Materials w/ Floodplains, Highly Sinuous, Stable Well Vegetated Banks, Very Low W/D

Type F - Entrenched in Highly Weathered Material, Gentle Gradients, High W/D, Meandering Laterally, Unstable w/ High Bank Erosion Rates

Type G - Gullies, Moderate Slopes, Low W/D Ratio, Narrow Valleys or Deeply Incised, Unstable, High Bank Erosion

Table 3-1. Channel Gradient, Sinuosity, Meander Width Ratios and Rosgen Stream Types
(Data from Rosgen, 1996)

Channel	Channel Gradient	Sinuosity	Width to Depth Ratio	Meander Width Ratio	Entrenchment Ratio	Rosgen Channel Type
Single	**High** Ave = 15.7% (5% - 47%)	**Low** Ave = 1.07 (1.0 - 1.4)	**Low** Ave = 7.9 (3 - 12)	**Low** Ave = 1.5 (1 - 3)	**Low** Ave = 1.24 (1.0 - 1.4)	**Type A**
	Moderate Ave = 3.0% (0.2% - 10%)	**Low** Ave = 1.33 (1.1 - 1.7)	**Moderate** Ave = 18.6 (11 - 39)	**Low** Ave = 3.7 (2 - 8)	**Low** Ave = 1.59 (1.2 - 2.2)	**Type B**
	Low Ave = 0.29% (0.02% - 1.3%)	**Very High** Ave = 2.26 (1.2 - 4.0)	**High** Ave = 29.8 (10 - 90)	**High** Ave = 11.4 (4 - 20)	**High** Ave = 3.71 (2.3 - 32.2)	**Type C**
	Moderate Ave = 1.63% (0.02% - 5.8%)	**Very High** Ave = 2.01 (1.2 – 3.1)	**Low** Ave = 7.1 (2 - 12)	**Very High** Ave = 24.2 (20 - 40)	**High** Ave = 41.13 (2.5 - ∞)	**Type E**
	Low Ave = 0.45% (0.01% - 2.4%)	**Moderate** Ave = 1.56 (1.4 - 2.0)	**High** Ave = 27.6 (12 - 95)	**Moderate** Ave = 5.3 (2 - 10)	**Low** Ave = 1.15 (1.0 - 1.4)	**Type F**
	Moderate Ave = 1.97% (0.03% - 3.9%)	**Low** Ave = 1.36 (1.2 - 1.6)	**Low** Ave = 8.0 (3 - 11)	**Low** Ave = 3.7 (2 - 8)	**Low** Ave = 1.22 (1.1 - 1.4)	**Type G**
Multiple	**Low** (< 4%)	Variable	n/a	**Low** Ave = 1.1 (1 - 2)	n/a	**Type D**
	Very Low (< 0.5%)	Variable	n/a	n/a	n/a	**Type DA**

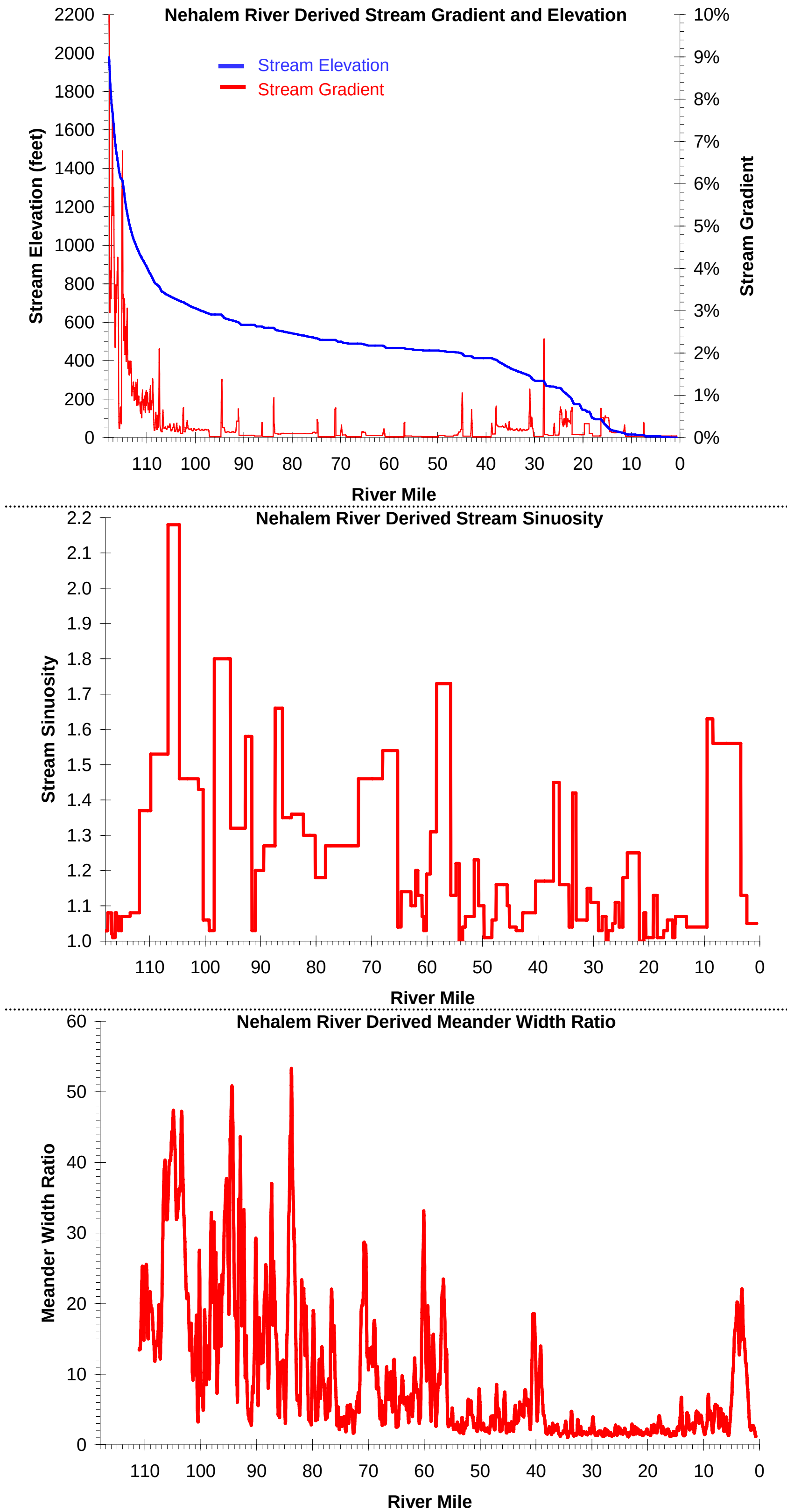


Figure 3-3. *Nehalem River - Stream Gradient, Sinuosity and Meander Width Ratio*

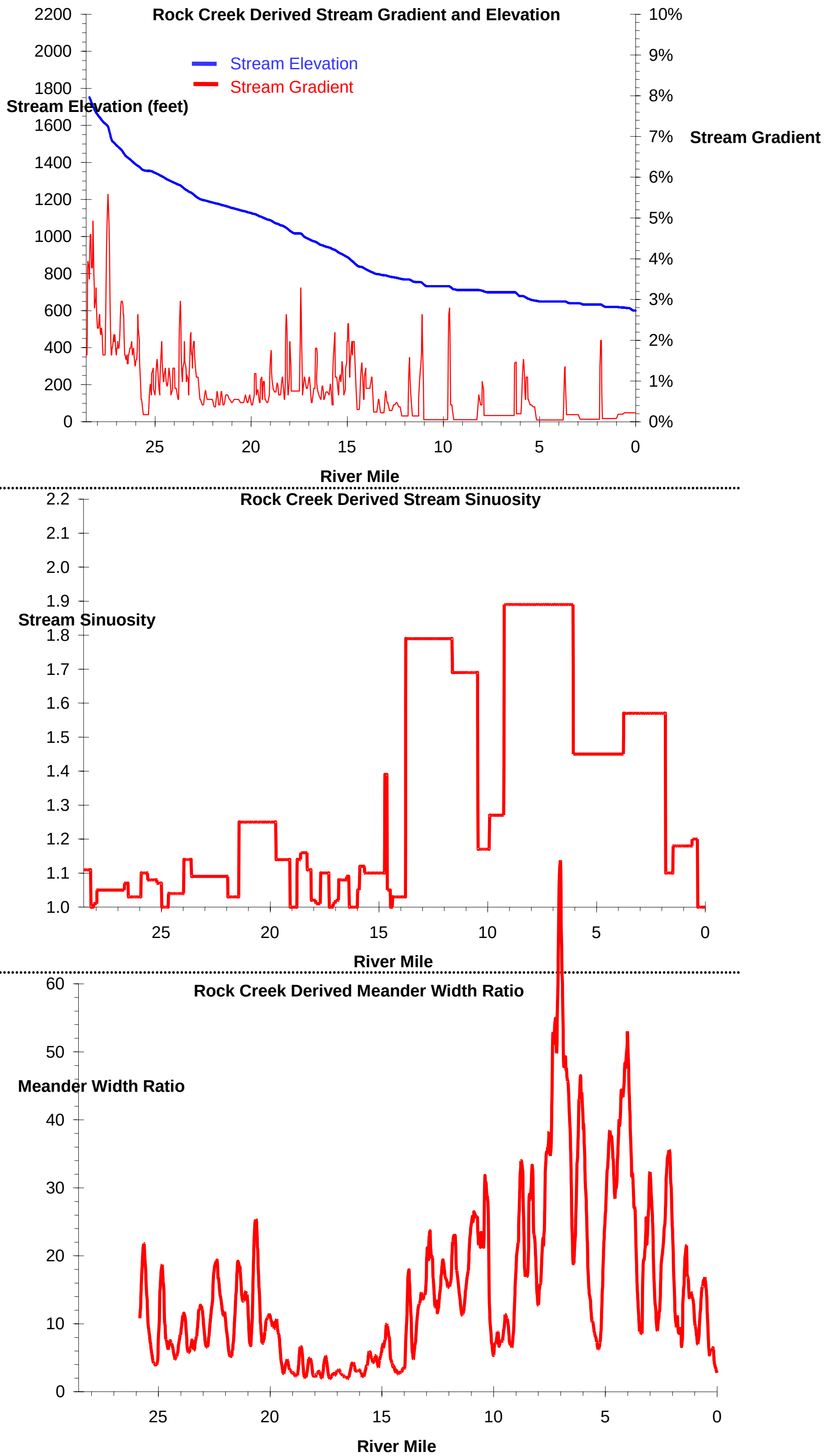


Figure 3-4. *Rock Creek - Stream Gradient, Sinuosity and Meander Width Ratio*

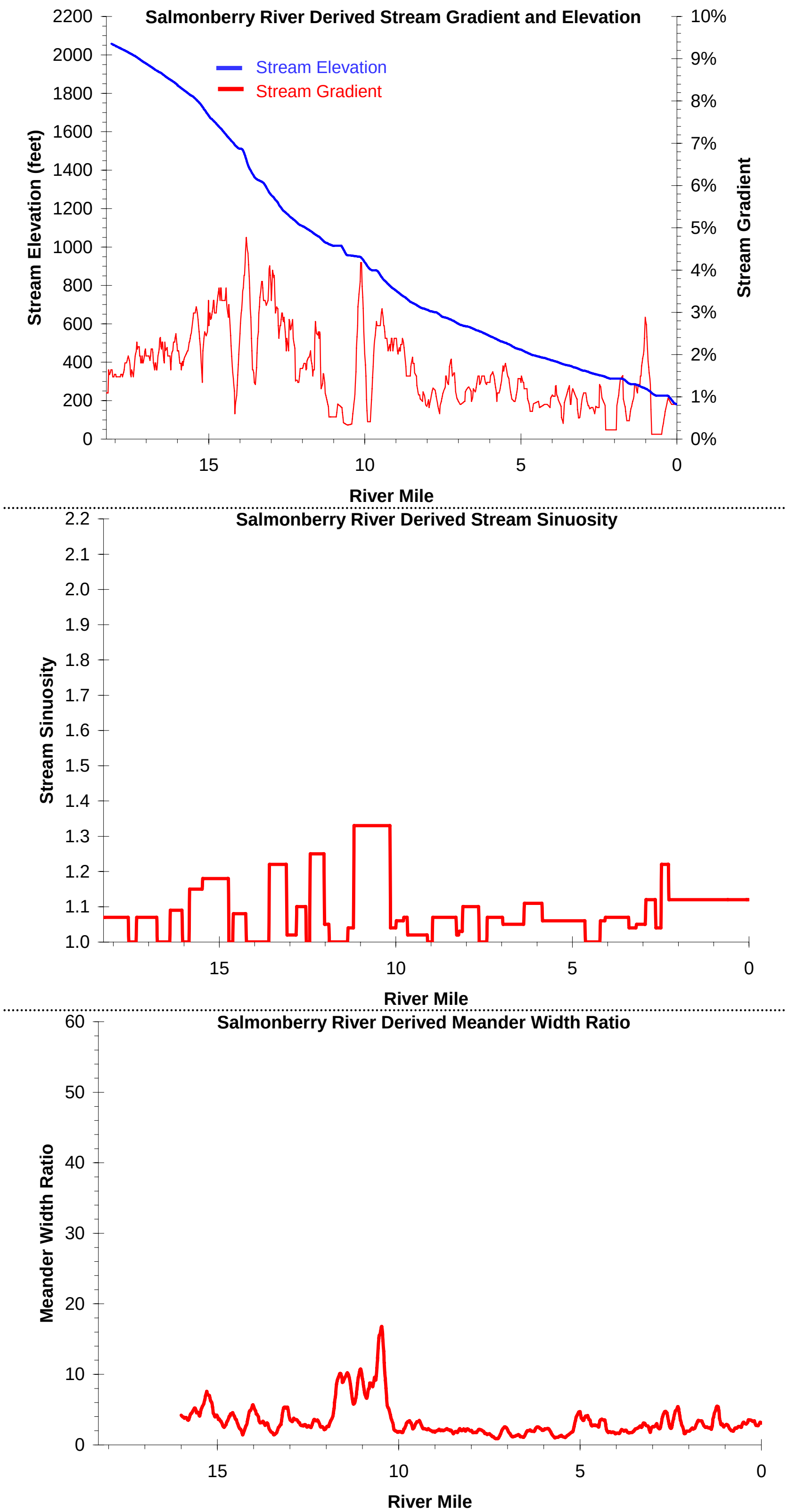


Figure 3-5. *Salmonberry River - Stream Gradient, Sinuosity and Meander Width Ratio*

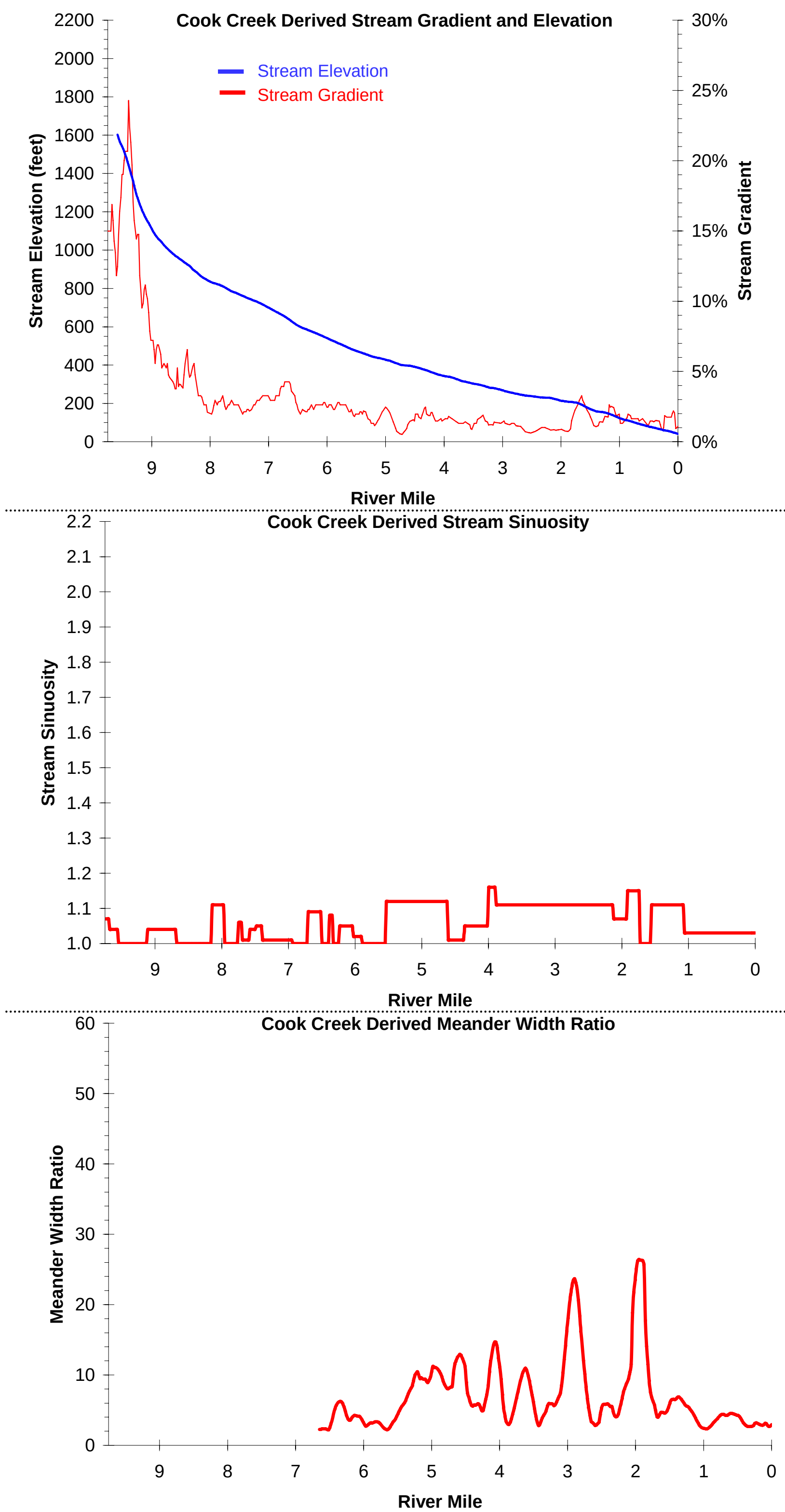


Figure 3-6. *Cook Creek - Stream Gradient, Sinuosity and Meander Width Ratio*

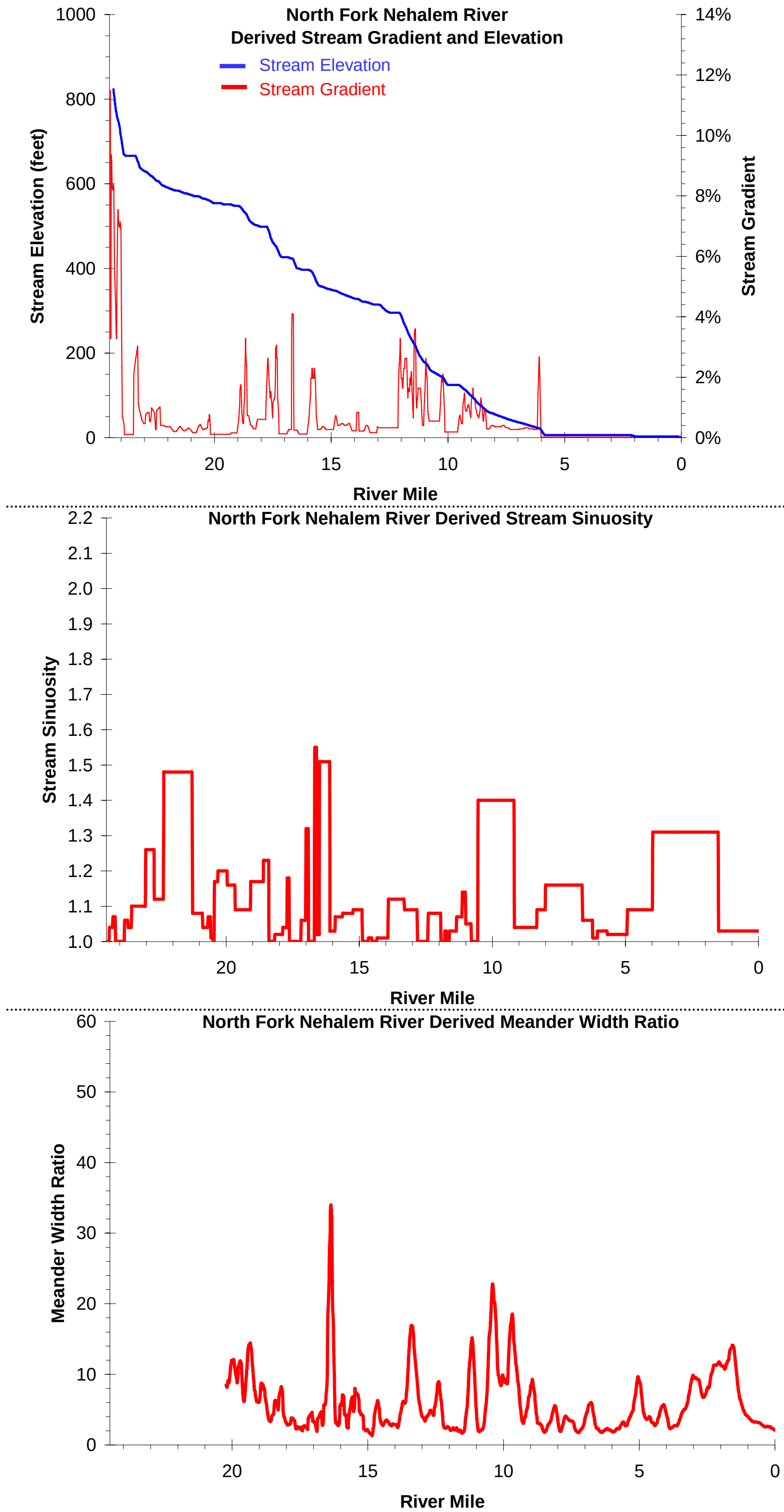


Figure 3-7. *North Fork Nehalem River - Stream Gradient, Sinuosity and Meander Width Ratio*

3.4.4 Channel Width Assessment

Channel width is an important component in stream heat transfer and mass transfer processes. Effective shade, stream surface area, wetted perimeter, stream depth and stream hydraulics are all highly sensitive to channel width. Accurate measurement of channel width across the stream network, coupled with other derived data, allows a comprehensive analytical methodology for assessing channel morphology. The step for channel width assessment are listed below and displayed in the graphics that follow.

Step 1. **Stream channel edges are digitized from DOQs at 1:5,000 or less**. These channel boundaries establish the near stream disturbance zone (NSDZ), which is defined for purposes of the TMDL, as the width between shade-producing near-stream vegetation. Where near-stream vegetation is absent, the near-stream boundary is used, defined as downcut stream banks or where the near-stream zone is unsuitable for vegetation growth due to external factors (i.e., roads, railways, buildings, etc.).

Step 2. **Sample near stream disturbance zone width at each stream data node using TTools**. The sampling algorithm measures the near stream disturbance zone width in the transverse direction relative to the stream aspect.

Step 3. **Compare sampled near stream disturbance zone width and ground level measurements**. Establish statistical limitations for near stream disturbance zone width values when sampled from aerial photograph (DOQ) analysis.

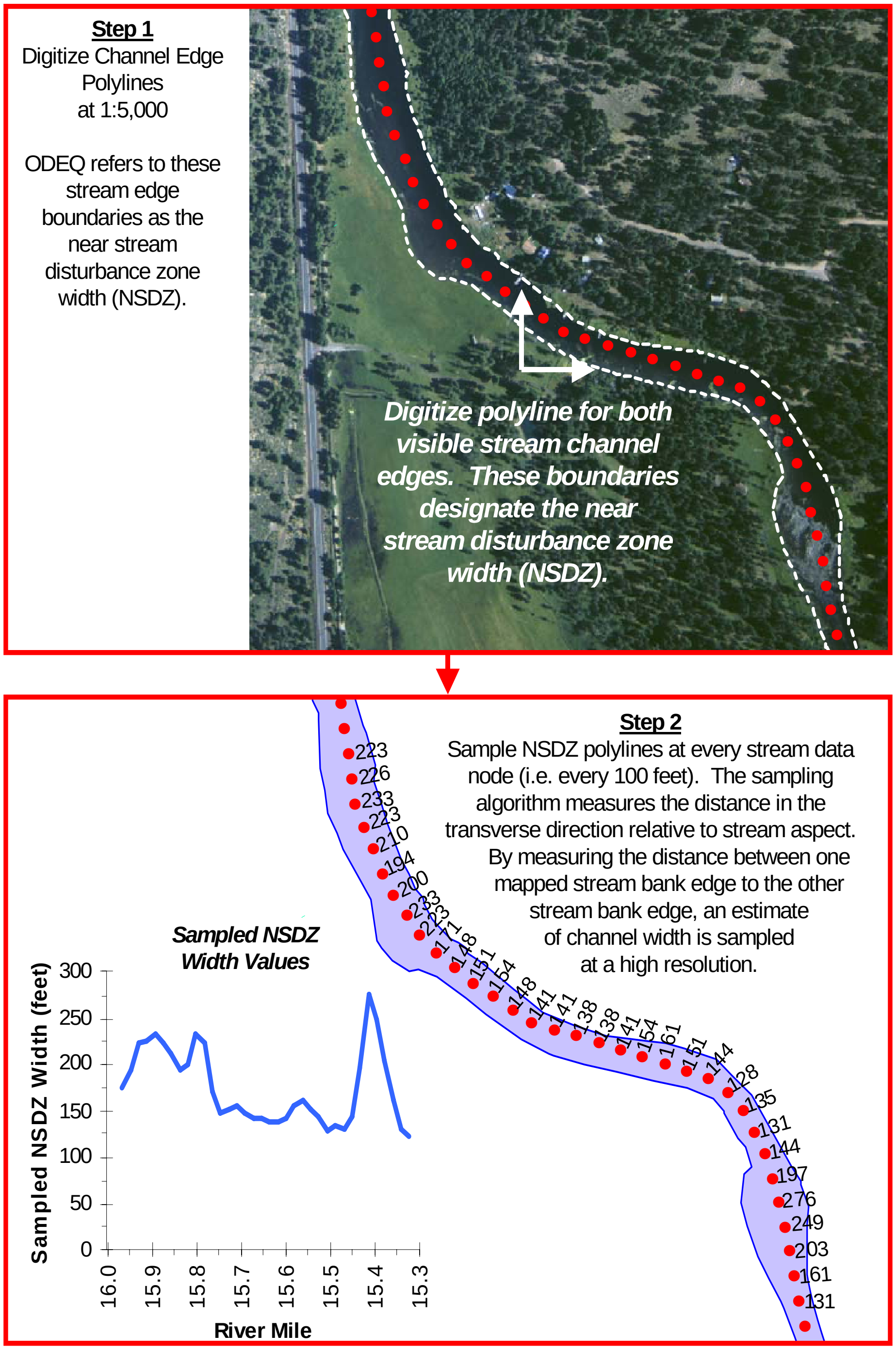
Step 4. **Perform Rosgen Level 1 channel classification**. As previously discussed, Rosgen Level 1 channel classifications were derived for selected streams in the Nehalem River subbasin. This analysis was performed using aerial photograph (DOQ) analysis and 10-meter DEMs.

Step 5. **Compute drainage areas.** The 10-meter digital elevation model (DEM) was used to compute the drainage areas of each stream, every 100 feet longitudinally.

Step 6. **Relate sampled NSDZ widths to drainage area and Rosgen Level 1 channel classification.** The channel morphology analysis was performed on Rock Creek, Salmonberry River, Cook Creek, North Fork Nehalem River, and the mainstem Nehalem River. Data for all five streams was combined into a single database. The data was then sorted according to Rosgen channel type. Sampled NSDZ widths and drainage areas were then plotted on opposing axes for each Rosgen channel type. A linear regression was applied to each data set. The upper 75% confidence limit of the regression then became the targeted maximum NSDZ. The upper 75% confidence limit was chosen as the target because it most accurately identified stream reaches where channel disturbance was apparent in the aerial photographs (DOQs) and ground level observations. Concurrently, the upper 75% confidence limit is not an overly restrictive target (i.e., most stream reaches have channels that are in fair condition or are already at their potential minimum NSDZ width). Standardized residuals were also plotted for each linear regression to demonstrate that the data is normally distributed and statistically valid.

Step 7. **NSDZ width targets are then incorporated into stream temperature modeling.** Maximum NSDZ width targets are then applied to each stream reach, based on drainage area and potential Rosgen channel type. Locations where the current NSDZ width exceeds the target have their NSDZ widths reduced to the target. Locations where the current NSDZ widths are at or below the target are unchanged.

Channel Width Assessment



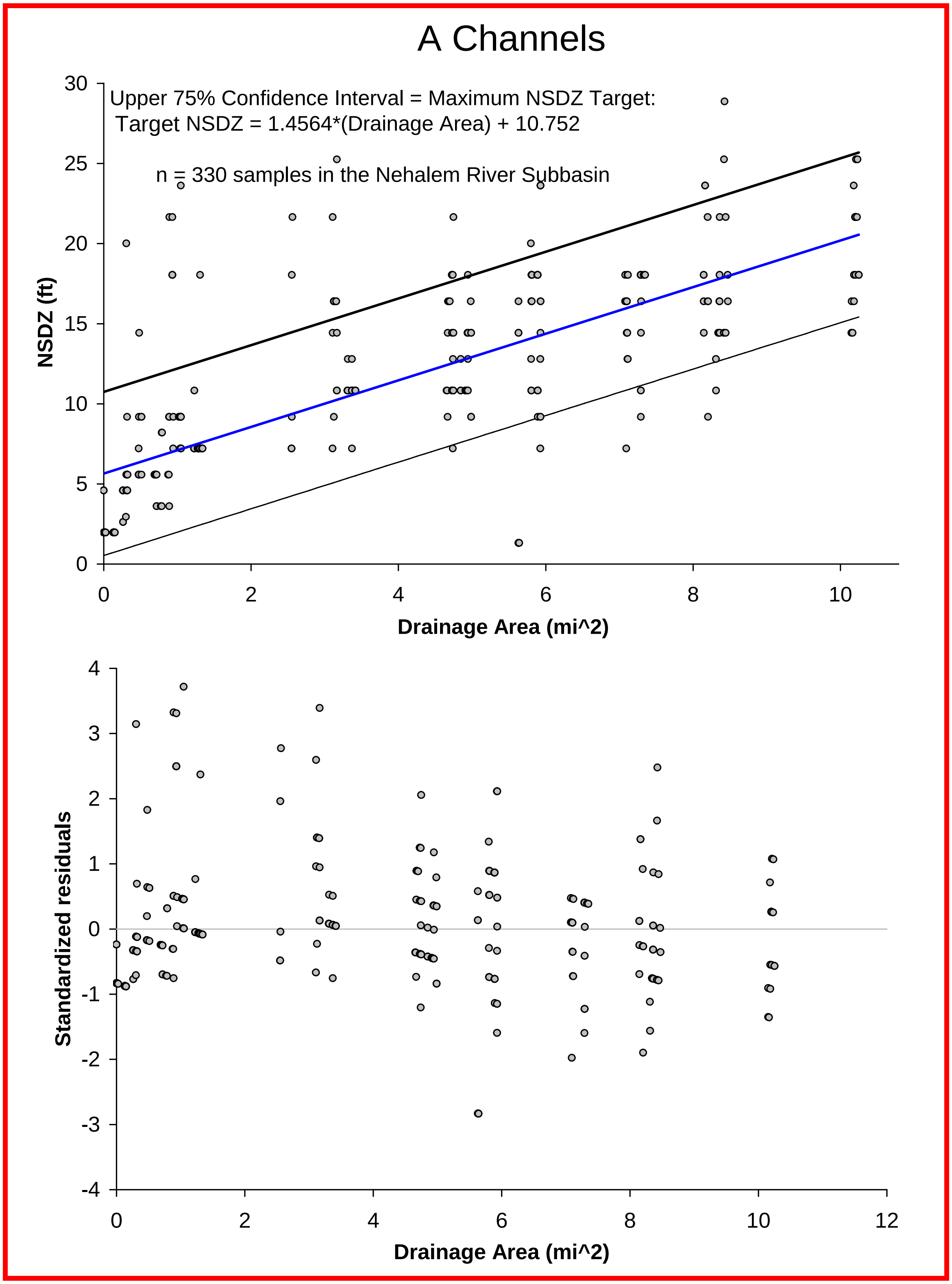


Figure 3-8. *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type A Channels.*

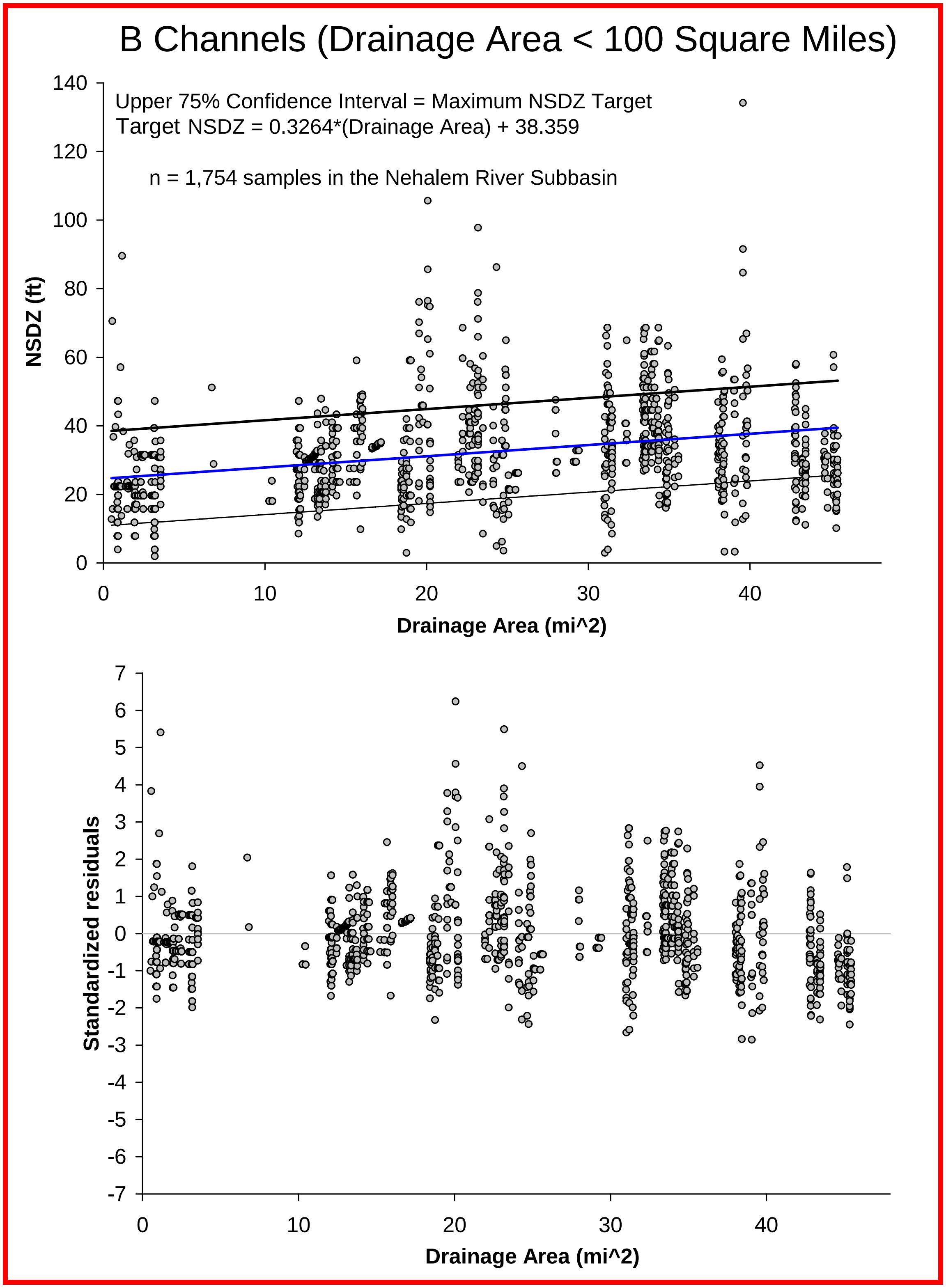


Figure 3-8 (continued). *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type B Channels.*

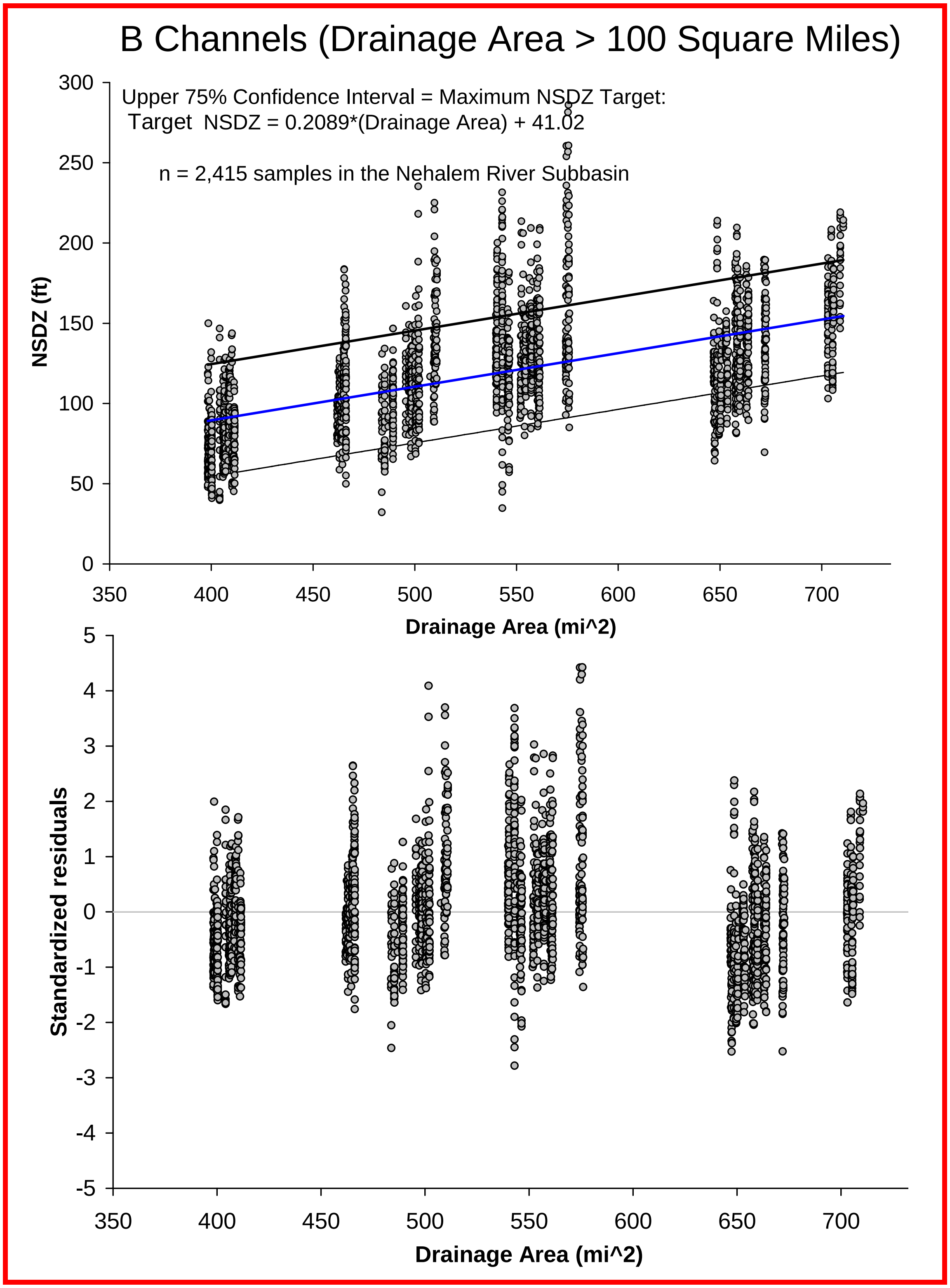


Figure 3-8 (continued). *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type B Channels.*

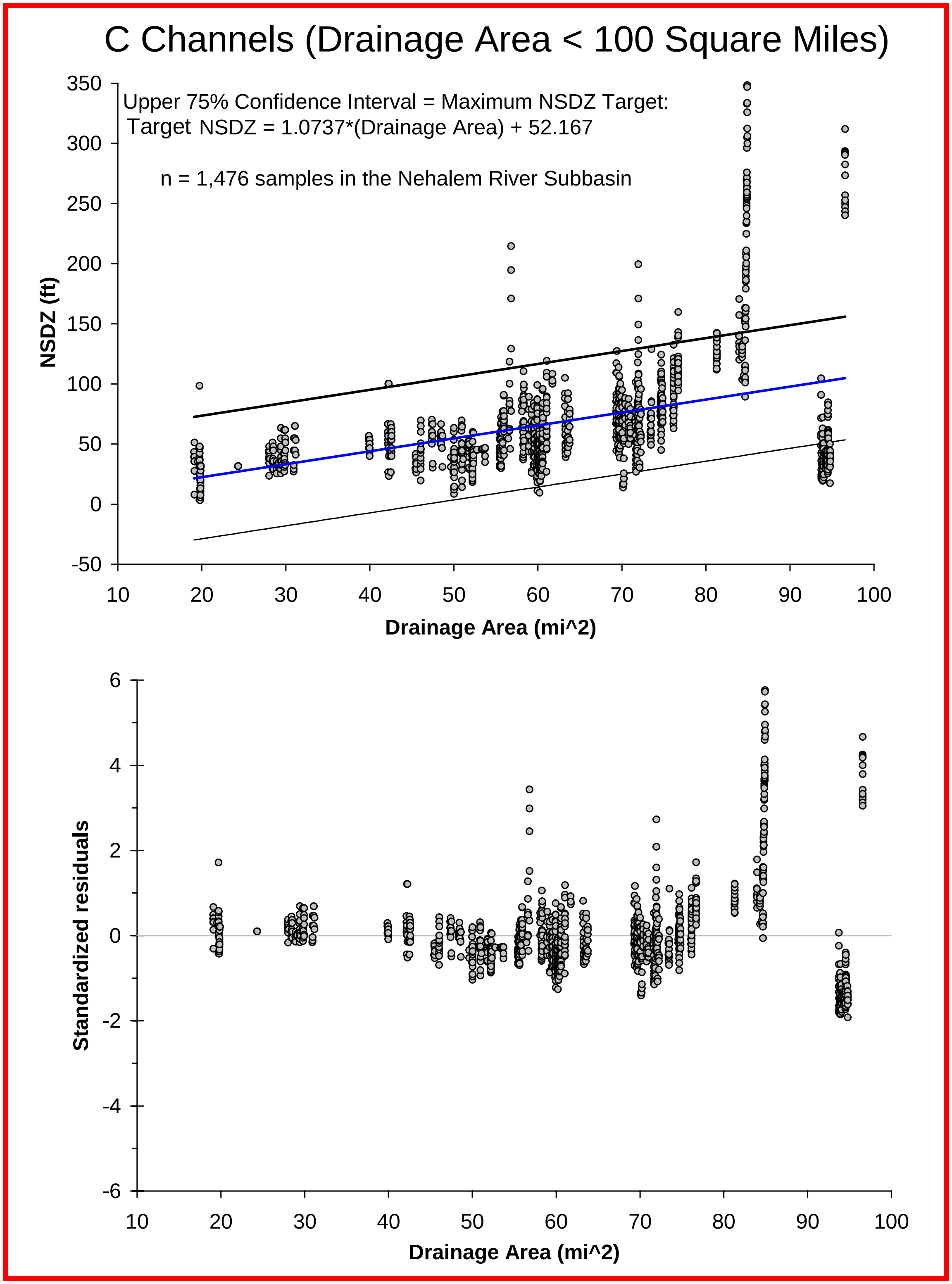


Figure 3-8 (continued). *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type C Channels.*

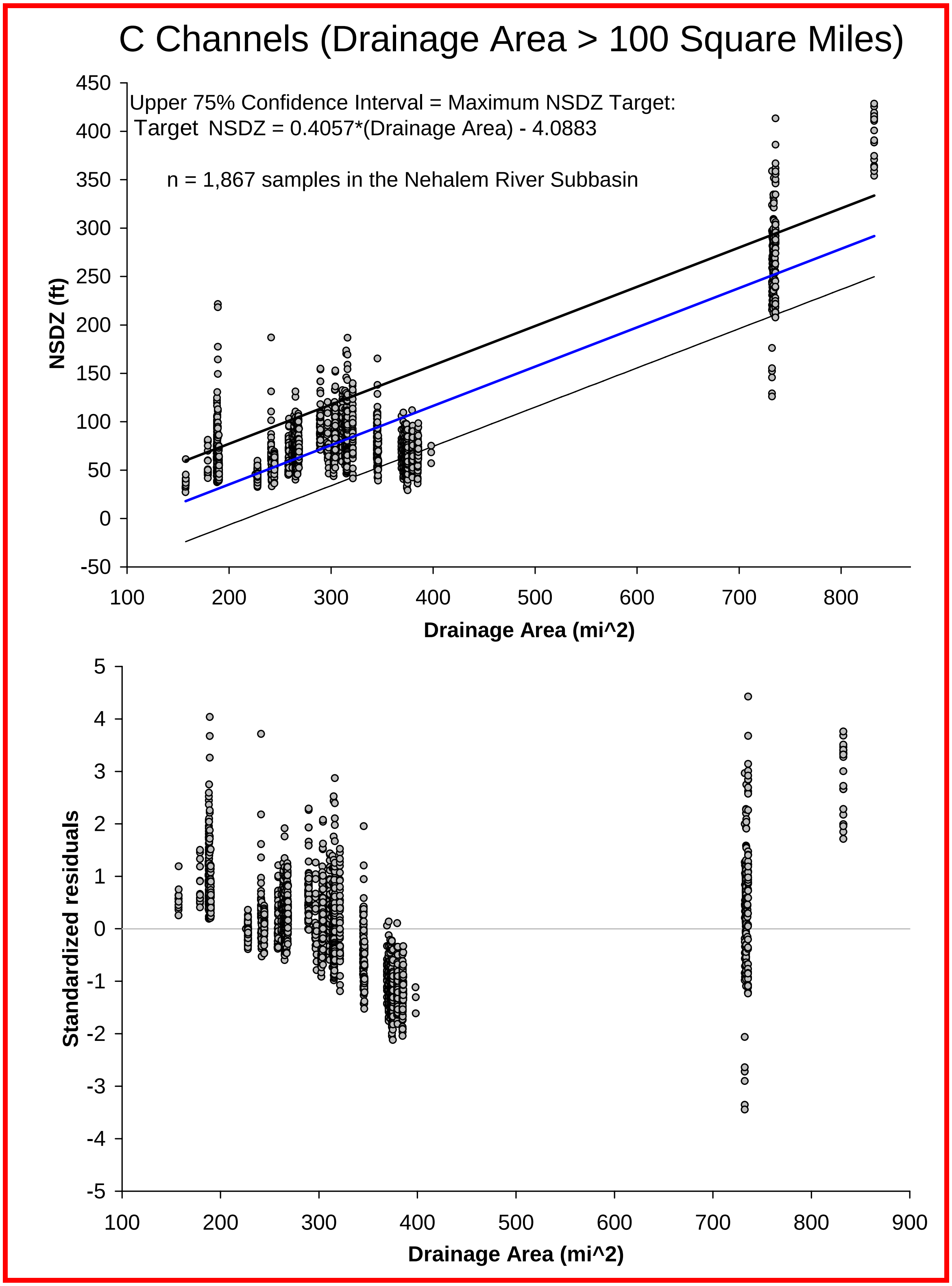


Figure 3-8 (continued). *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type C Channels.*

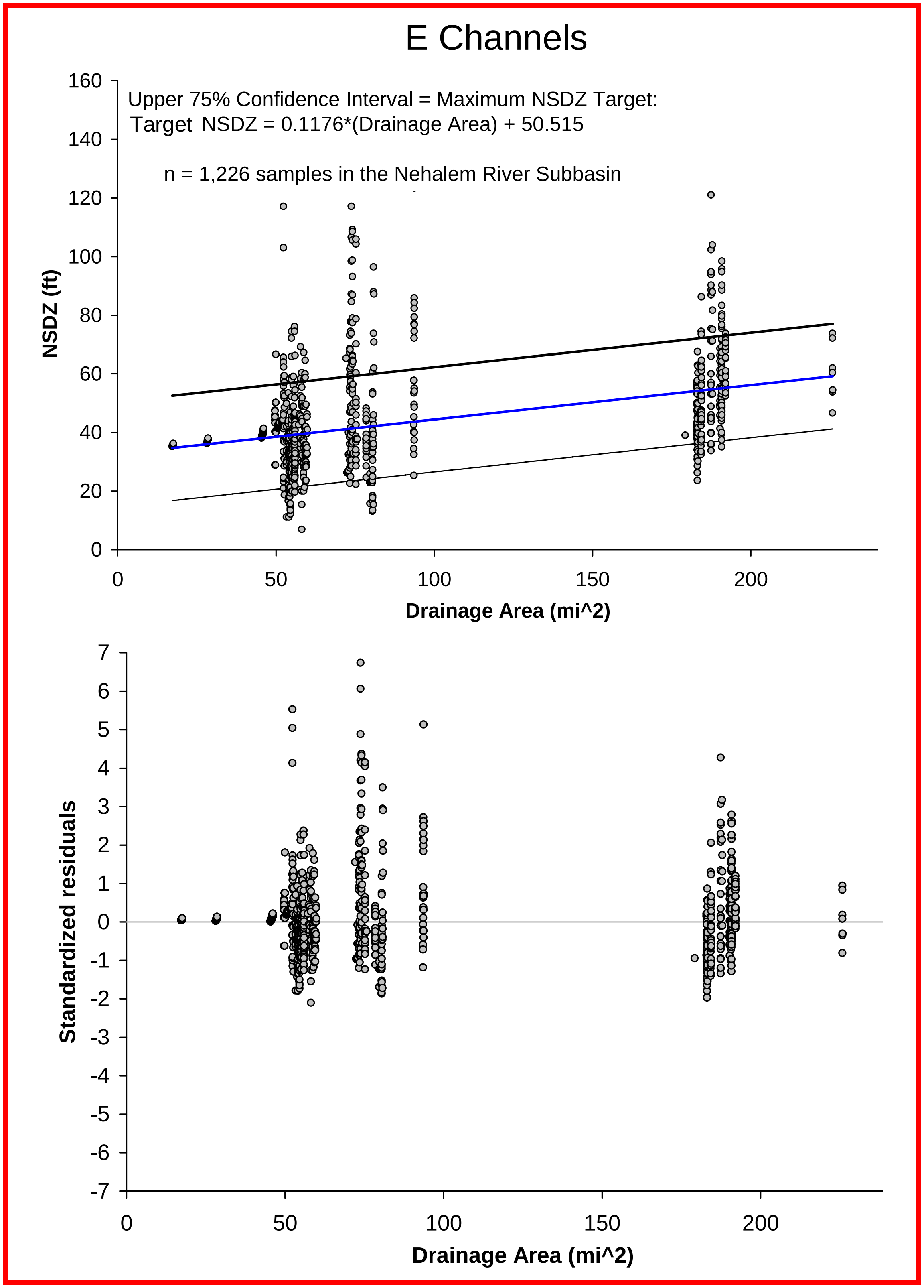


Figure 3-8 (continued). *Existing NSDZ widths plotted against drainage area, and the resulting 75% confidence interval NSDZ width target – Type E Channels.*

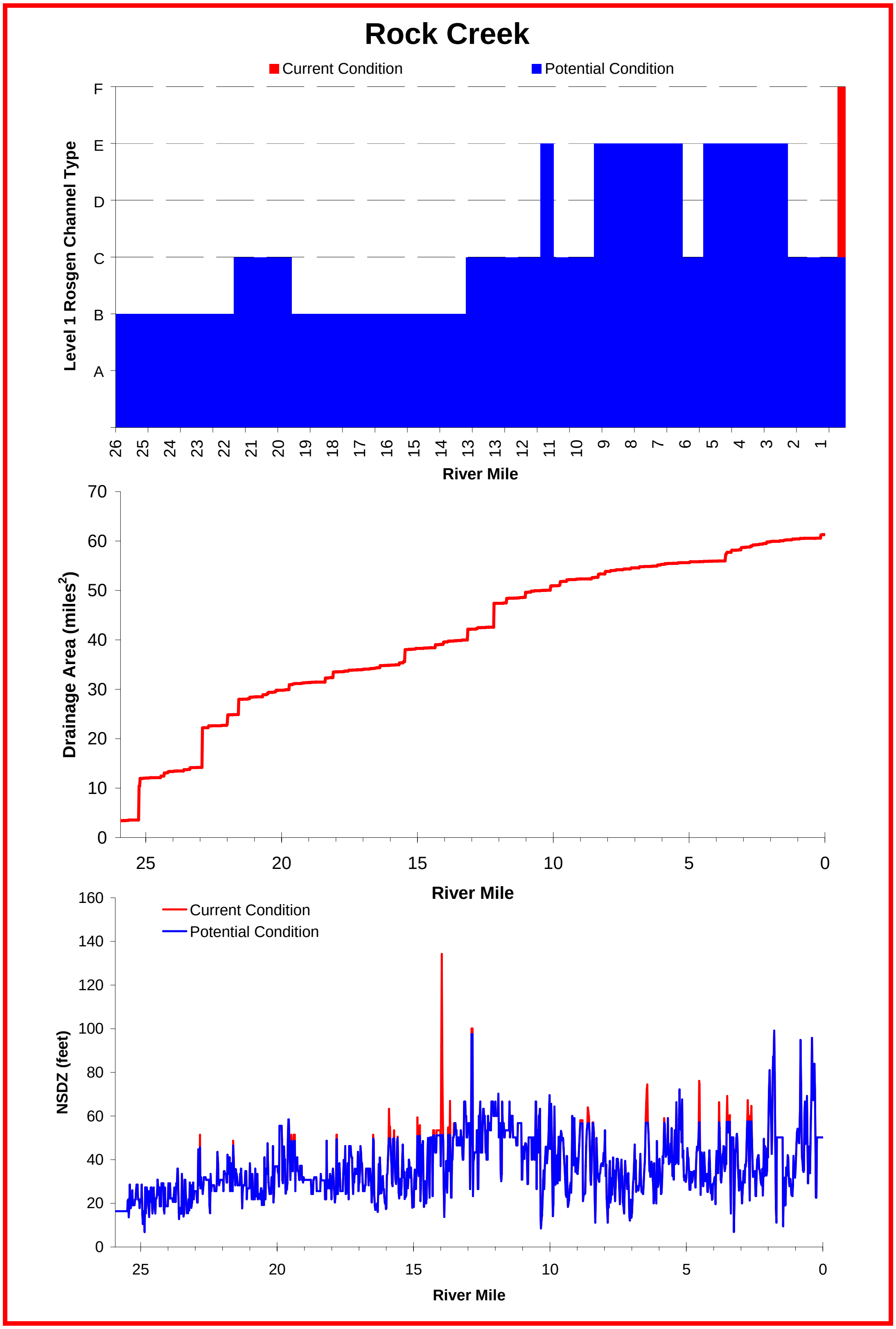


Figure 3-9. *Rock Creek channel types, drainage areas, and NSDZ width targets.*

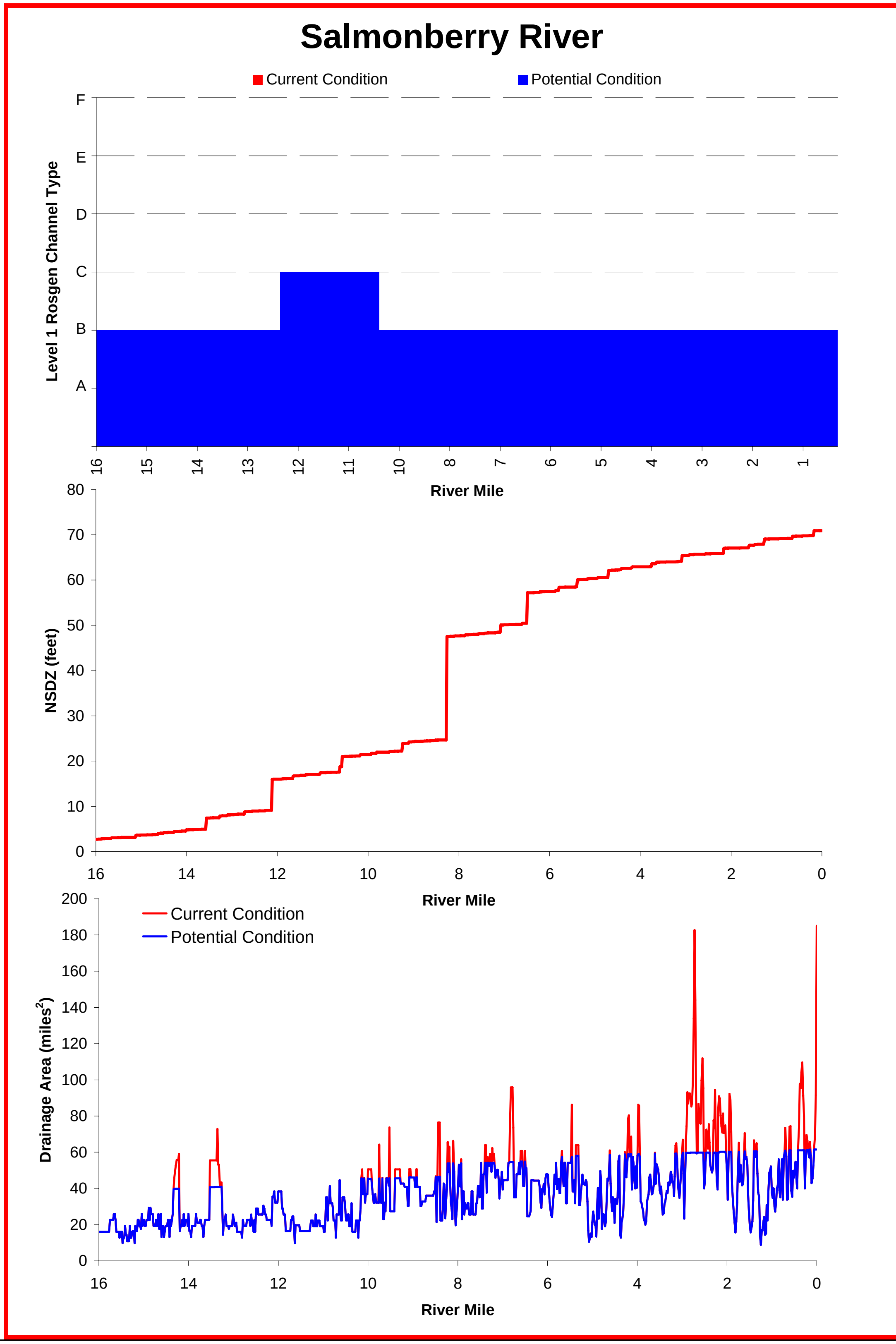


Figure 3-9 (continued). *Salmonberry River channel types, drainage areas, and NSDZ width targets.*

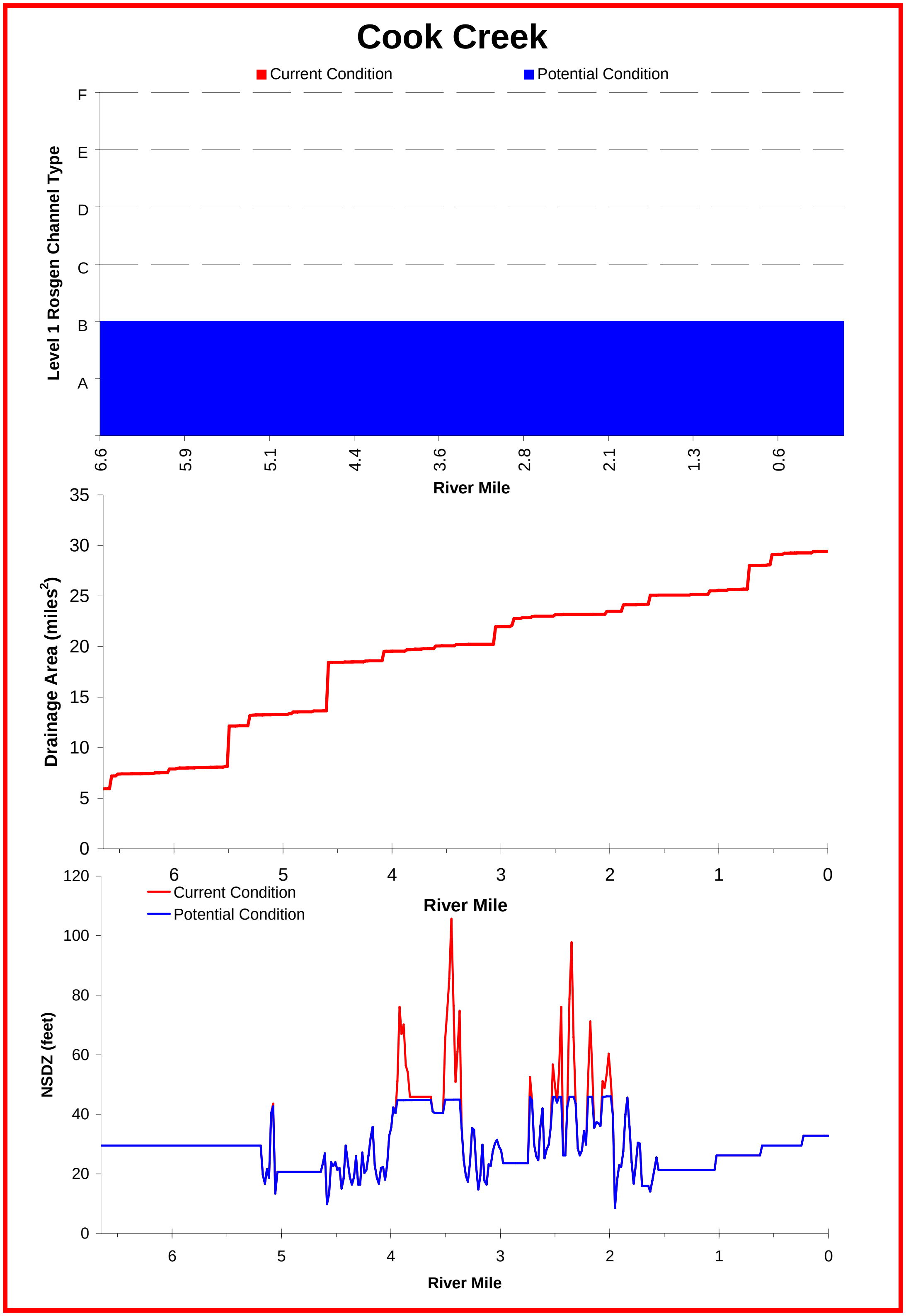


Figure 3-9 (continued). *Cook Creek channel types, drainage areas, and NSDZ width targets.*

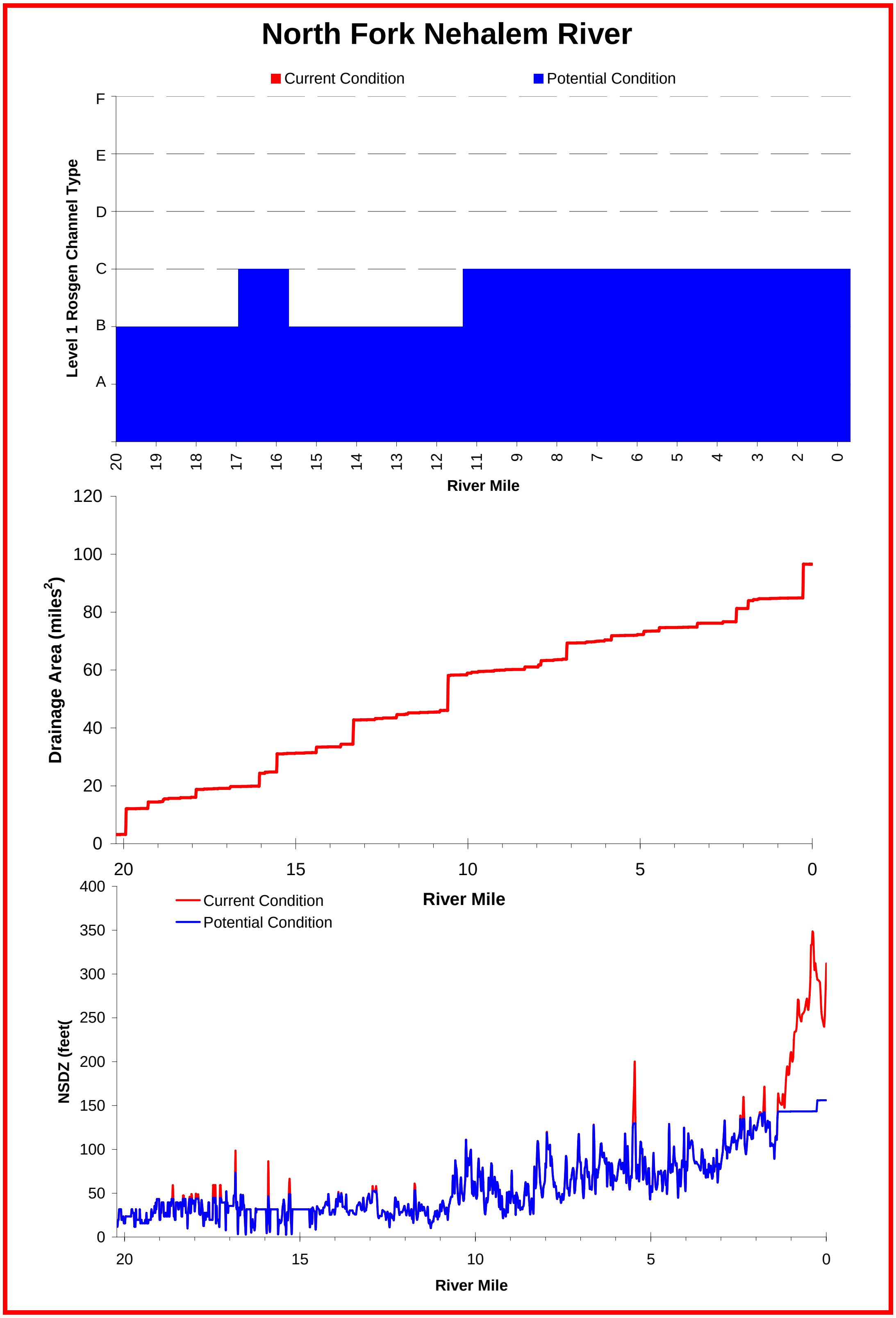


Figure 3-9 (continued). *North Fork Nehalem River channel types, drainage areas, and NSDZ width targets.*

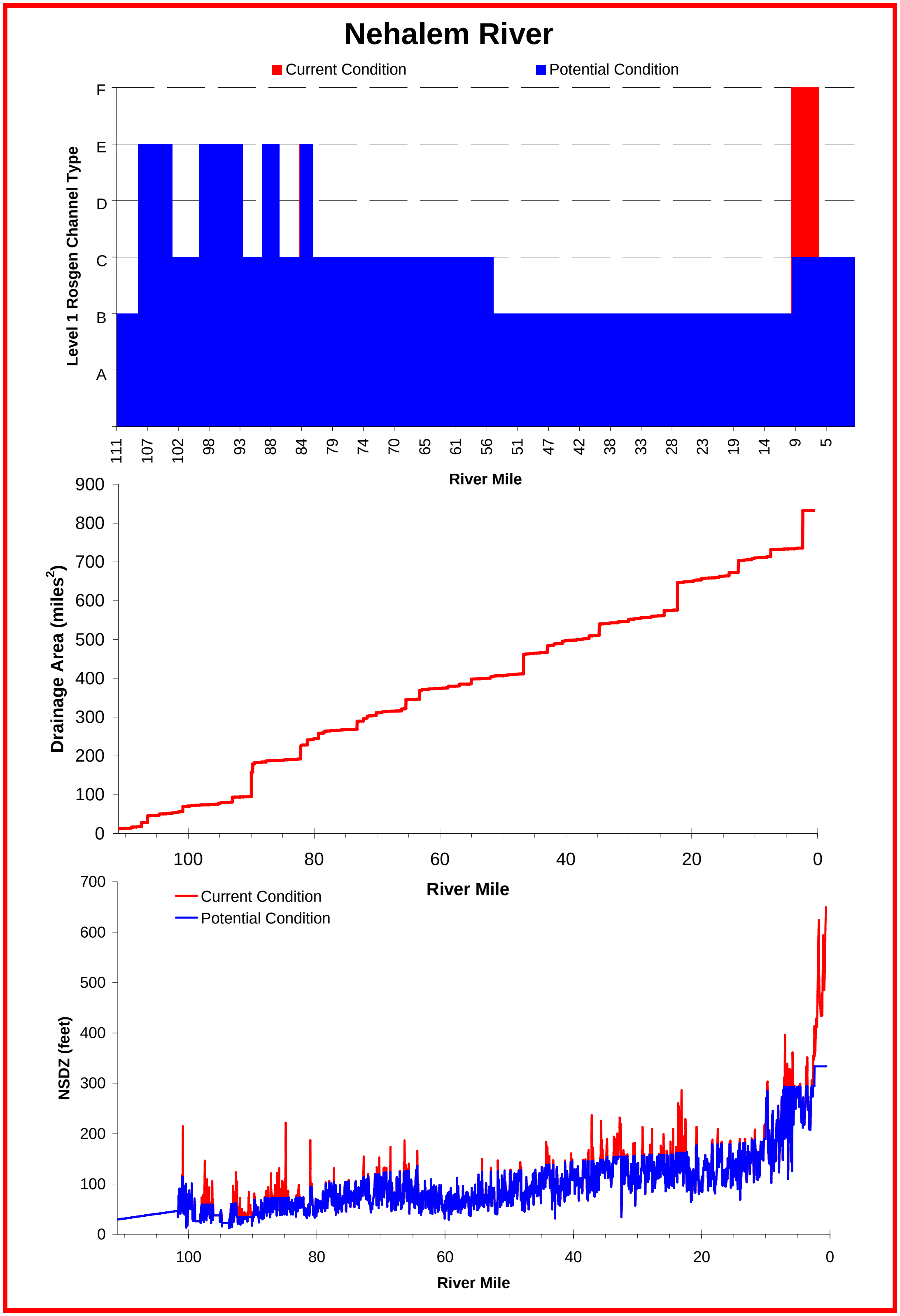


Figure 3-9 (continued). Nehalem River channel types, drainage areas, and NSDZ width targets.

3.5 NEAR STREAM LAND COVER

3.5.1 Near Stream Land Cover - Overview

The role of near stream land cover in maintaining a healthy stream condition and water quality is well documented and accepted in scientific literature (Beschta et al. 1987). The list of important impacts that near stream land cover has upon the stream and the surrounding environment is long and warrants listing.

- Near stream land cover plays an important role in regulating radiant heat in stream thermodynamic regimes.
- Channel morphology is often highly influenced by land cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris and influencing sedimentation, stream substrate compositions and stream bank stability.
- Near stream land cover creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity and lower wind speeds along stream corridors.
- Riparian and instream nutrient cycles are affected by near stream land cover.

With the recognition that near stream land cover is an important parameter in influencing water quality, DEQ made the development of land cover data sets in the North Coast Subbasins a high priority. Variable land cover conditions in the North Coast Subbasins require a higher resolution than currently available GIS data sources. To meet this need, Oregon DEQ has mapped near stream land cover using Digital Orthophoto Quads (DOQs) at a 1:5,000 scale. Land cover features were mapped 300 feet in the transverse direction from each stream bank. Land cover data is developed by DEQ in successive steps.

Step 1. Land cover polygons and stream polylines are digitized from DOQs. All digitized polygons are drawn to capture visually like land cover features. All digitized line work is completed at 1:5,000 or less.

Step 2. Basic land cover types are developed and assigned to individual polygons. The land cover types used in this effort are aggregate land cover groups, such as: conifers, hardwoods, shrubs, etc.

Step 3. WODIP satellite derived vegetation coverage (BLM, 2000) is merged with DEQ's 1:5000 land cover polygons where appropriate. WODIP was developed mainly for forested lands and thus applies mainly to upper stream reaches. WODIP accuracy was assessed on a site-specific basis via comparison to aerial photography (DOQs) and DEQ digitized land cover. The final product was a combination of WODIP and DEQ land cover classifications.

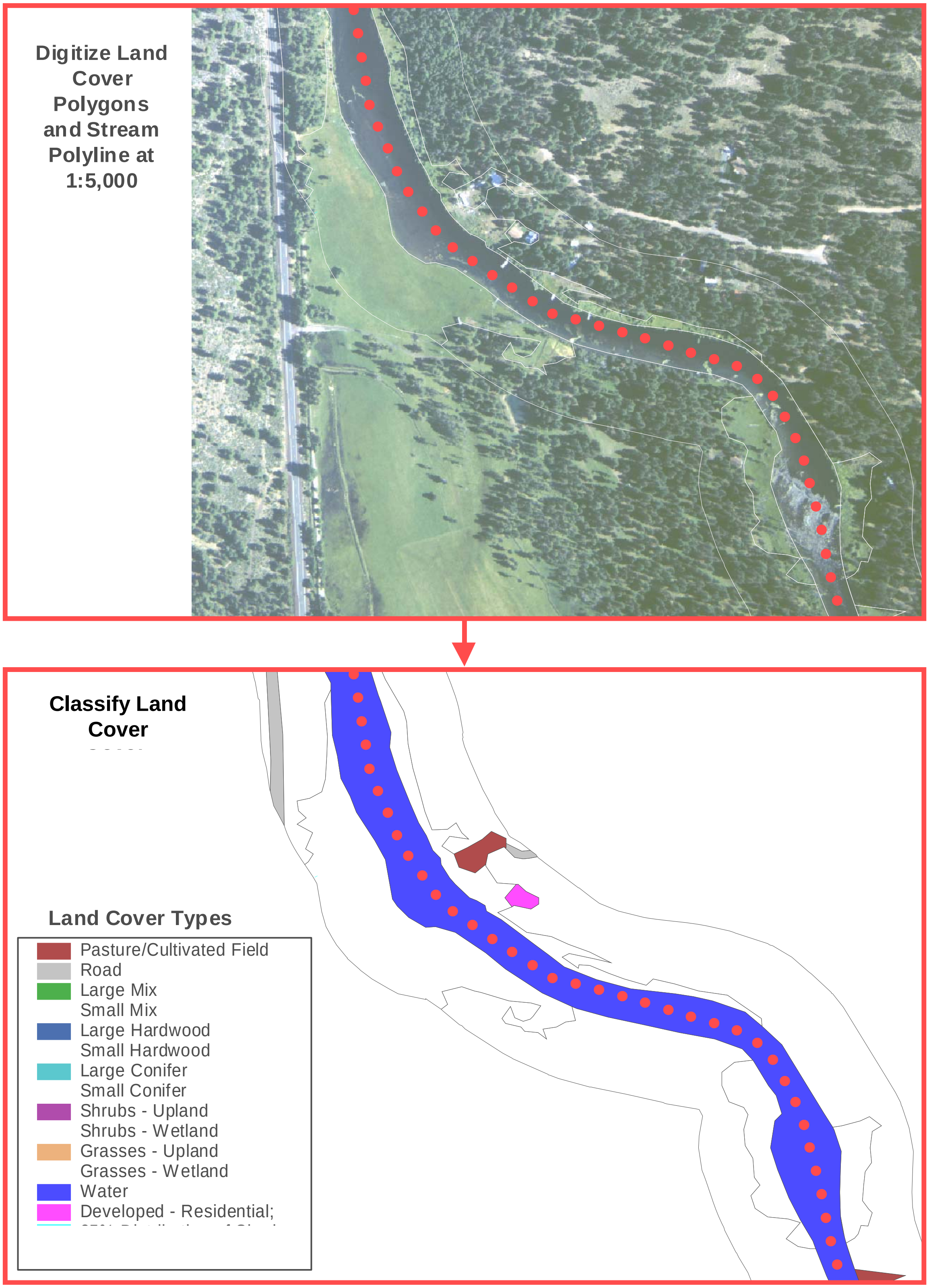
Step 4. Through simple assumptions regarding land cover succession and by examining land cover types adjacent to major anthropogenic disturbance areas (i.e., clearcuts, roads, cultivated fields, etc.), it is possible to develop a rule set that can be used to estimate potential land cover conditions. For example, small conifers are assumed to have the potential to become large conifers.

Step 5. Automated sampling is conducted on classified land cover spatial data sets in 2-dimensions. Every 100 feet along the stream (i.e., in the longitudinal direction), both stream banks are sampled every 15 feet, starting at the channel edge, out to 135 feet. This sampling rate results in 950 measurements of land cover per every mile of stream.

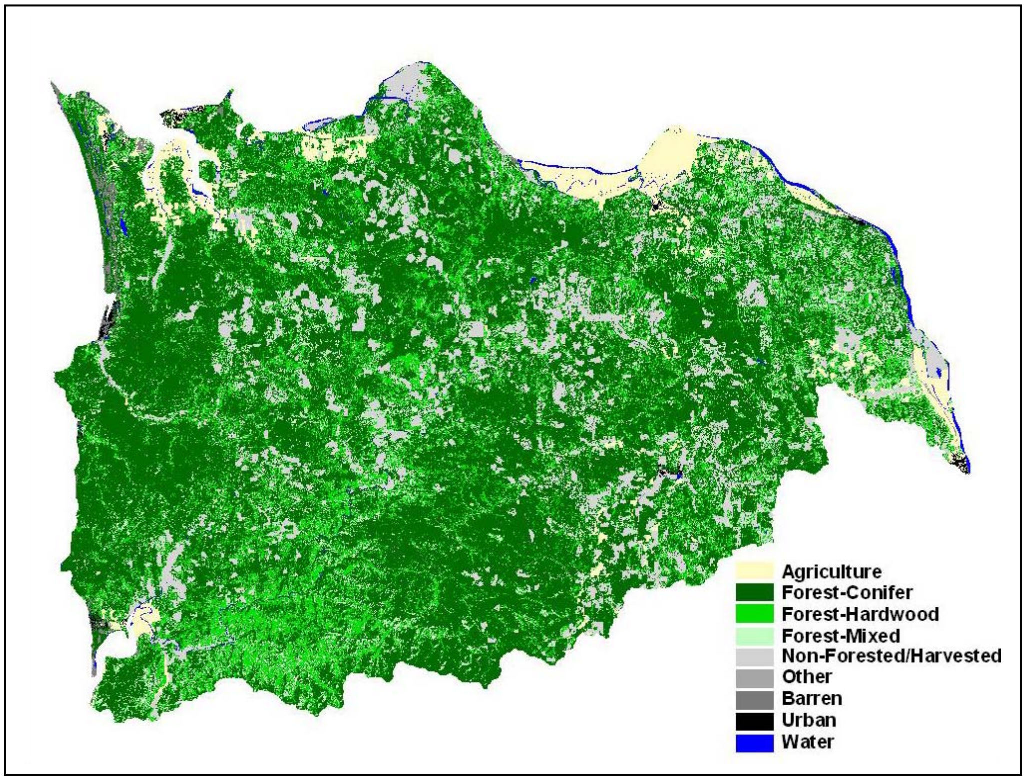
Step 6. Ground level land cover data is statistically summarized and sorted by land cover type. Median values for land cover height and density can then be used to describe DEQ land cover classifications. Growth curves were used to convert WODIP basal diameters to height values.

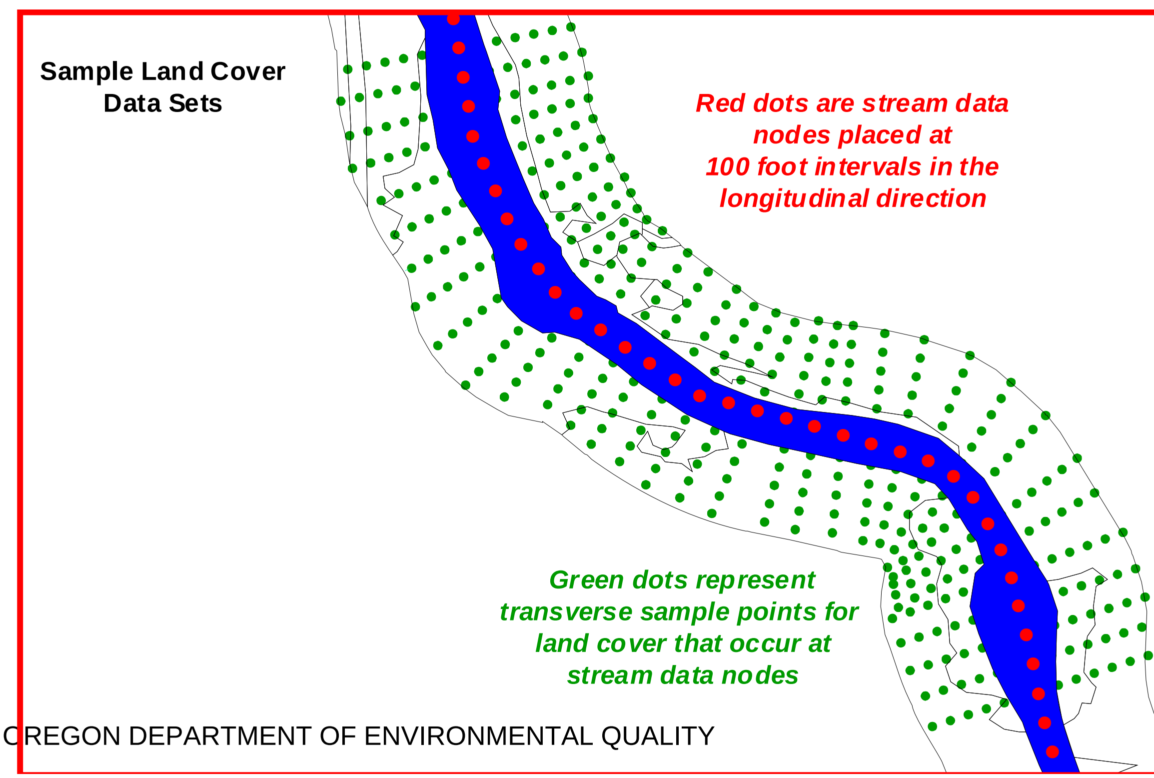
Step 7. Land cover physical attributes can then be described in 2-dimensions since automated sampling occurs in both the longitudinal and transverse directions.

Near Stream Land Cover Data Development


Digitize Land Cover Polygons and Stream Polyline at 1:5,000
Classify Land Cover
Land Cover Types
Pasture/Cultivated Field
Road
Large Mix
Small Mix
Large Hardwood
Small Hardwood
Large Conifer
Small Conifer
Shrubs - Upland
Shrubs - Wetland
Grasses - Upland
Grasses - Wetland
Water
Developed - Residential;

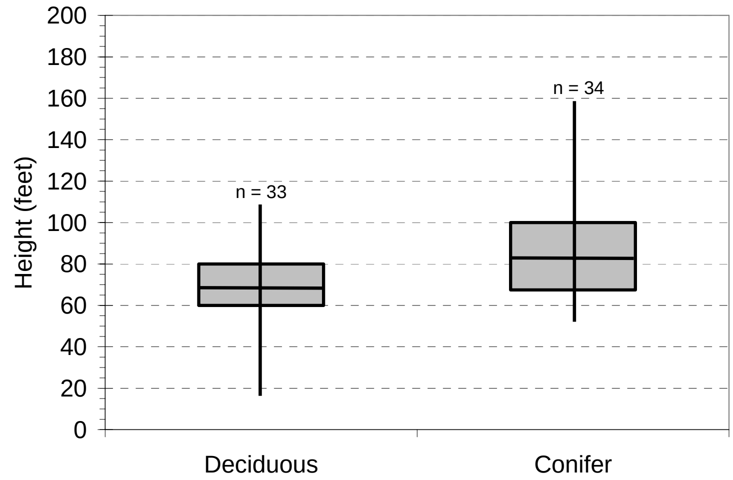
Near Stream Land Cover Data Development



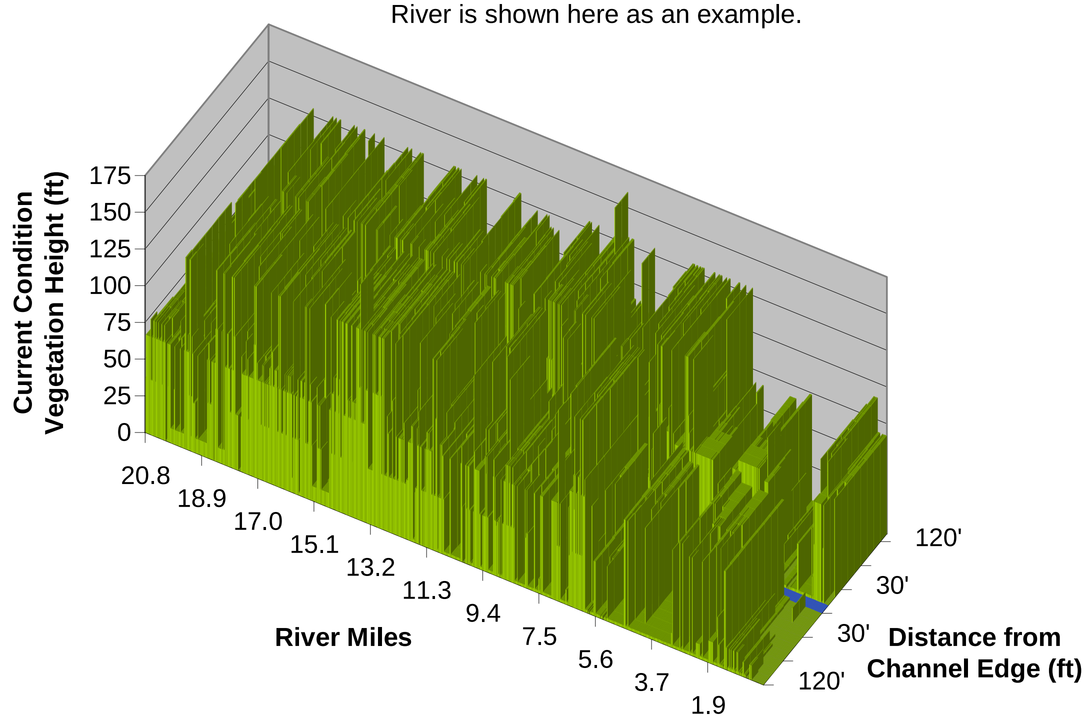


Near Stream Land Cover Data Development

Ground level landcover data is statistically summarized and sorted by vegetation type. Median values allow a general description based on site specific data collected in the study area. Vegetation height is shown here.



Using the median values for each land cover type, vegetation height can be assigned to 1:5000 digitized polygons. WODIP derived heights are then combined with the 1:5000 digitized polygon coverage. The derived data is 2-dimensional since it is sampled in the transverse and longitudinal directions. The Necanicum River is shown here as an example.



3.5.2 Near Stream Land Cover - Mapping, Classification and Sampling

DEQ grouped land cover species into deciduous and coniferous land cover types. Data were then statistically summarized by land cover type to determine the average land cover heights and variability within the data stratification. As would be expected, variability in height increased with taller growing land cover types. A possible weakness in the data set is the relatively small sample sizes high variability. Also note the lack of data for the Lower Columbia subbasin. The assumption was made that the land cover features in the Lower Columbia subbasin are relatively similar to those of the other three North Coast Subbasins. **Figure 3-10** shows locations where DEQ collected ground level near stream land cover data. **Table 3-2** presents summarized near stream land cover height statistics derived from ground level data.

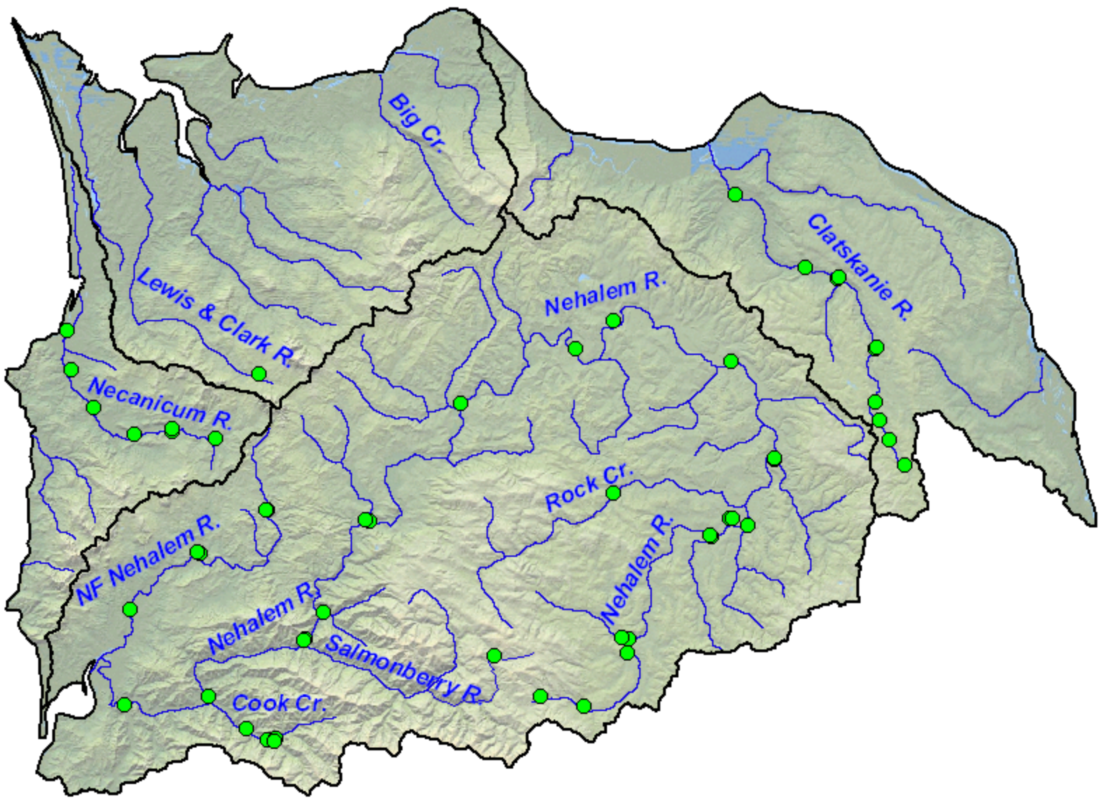


Figure 3-10. *Ground level near stream land cover assessment sites.*

Table 3-2. Ground Level Sampled Near Stream Land Cover Summary Statistics

Land cover Type	Samples	Median Height (feet)	Average Height (feet)	Standard Deviation (feet)	Maximum Height (feet)	Minimum Height (feet)
Conifer	34	80.0	83.6	36.7	160	50
Deciduous	33	70.0	67.0	33.2	108	15

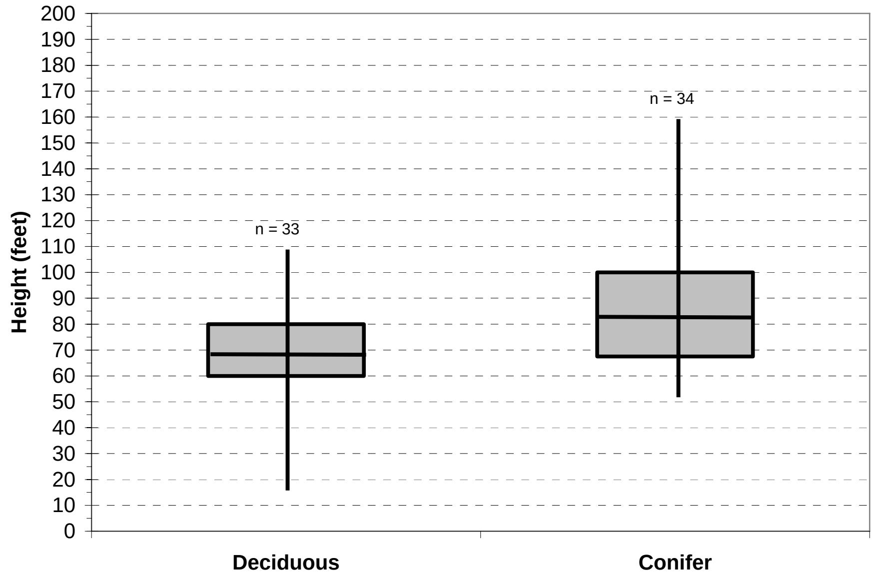


Figure 3-11. *Summarized near stream land cover height data from North Coast Subbasins.*

Land cover classifications developed by DEQ are presented in **Table 3-3**. These classifications were developed using the following criteria/assumptions:

- Average statistics developed from ground level data (**Table 3-2**) are used to assign land cover height and density classifications.
- Several land cover classifications assumed zero height, density and overhang attributes. These include all classifications for barren, water, channel bottom, and instream structures (dam/weir/canal).
- Development classification attempts to estimate heights and density (100%) of structures (e.g. houses, buildings, etc.)
- Overhanging land cover refers to the horizontal distance that land cover occupies from the channel edge extending over the stream channel. These values are assumed as follows:

Conifer Overhanging Distance = 10.0% land cover Height
Hardwood Overhanging Distance = 15.0% land cover Height
Mixed Conifer/Hardwood Overhanging Distance = 12.5% land cover Height
Non-Woody Land cover Overhanging Distance = 0% land cover Height

Table 3-3. DEQ/PSU Vegetation and Land Cover Classifications for Digitized Polygons

Classification Code	Land Cover Description	Land cover Height (feet)	Land cover Density	Overhanging Land cover (feet)
1032	Conifer Medium Dense	81.0	75%	8.1
1031	Conifer Medium Sparse	81.0	25%	8.1
1022	Conifer Small Dense	40.5	75%	4.1
1021	Conifer Small Sparse	40.5	25%	4.1
1013	Barren Clearcut	2.0	90%	0.0
1012	Conifer Regeneration Dense	10.0	75%	1.0
1011	Conifer Regeneration Sparse	10.0	25%	1.0
932	Mixed Medium Dense	74.0	75%	9.2
931	Mixed Medium Sparse	74.0	25%	9.2
922	Mixed Small Dense	37.1	75%	4.6
921	Mixed Small Sparse	37.1	25%	4.6
903	Wetland	2.0	90%	0.0
902	Tree Farm	67	90%	10.0
901	Dike	0.0	100%	0.0
900	Hatchery	0.0	100%	0.0
832	Hardwood Medium Dense	67	75%	10.0
831	Hardwood Medium Sparse	67	25%	10.0
822	Hardwood Small Dense	33.5	75%	5.0

821	Hardwood Small Sparse	33.5	25%	5.0
700	Shrub	10.0	75%	1.5
601	Agriculture	2.0	90%	0.0
600	Grass	2.0	90%	0.0
500	Water/NSDZ	0.0	100%	0.0
400	Bare Ground	0.0	100%	0.0
300	Road	0.0	100%	0.0
200	Rail Road	0.0	100%	0.0
100	Structure	15.0	100%	0.0

It is important to remember that DEQ near stream land cover polygons were combined with WODIP satellite vegetation coverage (BLM, 2000). Land areas where WODIP successfully classified forest vegetation were used. Site specific comparisons between WODIP classifications and DOQs were the method used to determine WODIP accuracy. **Table 3-6** displays the WODIP code descriptions and associated vegetation dimensions. All WODIP tree heights were derived from the recorded diameter at breast height (DBH) values using growth curves.

For WODIP coverages, existing tree heights were either calculated from the specified DBH using species-specific growth curves (Hann, 1997 and Richards 1959). WODIP classifications provide DBH in ranges allowing calculation of vegetation height based on “growth curve” information developed for forestry practices. DEQ applied the middle (average) value of the range for each size/structure class (**Table 3-4**). Below is the Chapman-Richards Asymptotic Nonlinear Regression Module equation that is used to determine heights based on known DBH values (Richards, 1959).

Table 3-6 displays (WODIP) tree height as a function of DBH using the Chapman-Richards Asymptotic Nonlinear Regression Module (**Equation 1**) and the coefficients presented in **Table 3-4**. The North Coast Subbasins are home to tall-growing conifers such as: Douglas fir, western hemlock, Sitka spruce, noble fir and western red cedar. Predominant deciduous trees include red alder and big-leaf maple.

Equation 1. Chapman-Richards Asymptotic Nonlinear Regression Module (Hann, 1997 and Richards 1959),

$$H = 1.37 + \left(b_o\left[1 - \exp\left(b_1 \cdot DBH\right)\right]^{b_2}\right)$$

Where,

H =

Height of Tree

b_0 =

regression variable

b_1 =

regression variable

b_2 = regression variable

DBH =

Diameter at Breast Height

Table 3-4. Mean vegetation DBH and Height for North Coastal Tree Species (Hann, 1997 and Richards 1959)			
Species	**Mean DBH (inches)**	**Mean Height (feet)**	**Sample Size N**
Bigleaf Maple	11.3	62.6	627
Douglas Fir	19.1	100.7	8332
Noble Fir	17.1	71.8	68
Red Alder	9.2	57.4	1641
Sitka Spruce	40.0	147.3	423
Western Hemlock	14.9	97.7	3152
Western Red Cedar	18.9	72.8	582

Table 3-5. Chapman-Richards Asymptotic Nonlinear Regression Module Coefficients (Hann, 1997 and Richards 1959)				
Species	**b_0**	**b_1**	**b_2**	**R^2**
Bigleaf Maple	30.17141	-0.03738	0.81291	0.69
Douglas Fir	85.60765	-0.01023	0.93495	0.92
Noble Fir	75.47281	-0.00861	0.97062	0.94
Red Alder	37.36855	-0.02340	0.76164	0.75
Sitka Spruce	65.27757	-0.01236	0.96792	0.71
Western Hemlock	60.87614	-0.02195	1.07827	0.86
Western Red Cedar	55.19896	-0.01211	0.91076	0.91

Table 3-6. WODIP Land Cover Data				
Classification Code	**Land Cover Description**	**Land cover Height (feet)**	**Land cover Density**	**Overhanging Land cover (feet)**
1	Water	0.0	0%	0.0
2	Agriculture	1.6	95%	0.0
3	Non_Forest	10.0	80%	2.0
4	Grass/Bushes	2.5	95%	2.5
5	Other	10.0	80%	2.0
6	Clearcut	2.5	95%	0.0
7	Conifer-Small-1Story	37.4	5%	3.7
8	Conifer-Small-1Story	37.4	15%	3.7
9	Conifer-Small-1Story	37.4	25%	3.7
10	Conifer-Small-1Story	37.4	35%	3.7
11	Conifer-Small-1Story	37.4	45%	3.7
12	Conifer-Small-1Story	37.4	55%	3.7
13	Conifer-Small-1Story	37.4	65%	3.7
14	Conifer-Small-1Story	37.4	75%	3.7
15	Conifer-Small-1Story	37.4	85%	3.7
16	Conifer-Small-1Story	37.4	95%	3.7
17	Conifer-Medium-1Story	90.2	5%	9.0
18	Conifer-Medium-1Story	90.2	15%	9.0
19	Conifer-Medium-1Story	90.2	25%	9.0
20	Conifer-Medium-1Story	90.2	35%	9.0
21	Conifer-Medium-1Story	90.2	45%	9.0
22	Conifer-Medium-1Story	90.2	55%	9.0
23	Conifer-Medium-1Story	90.2	65%	9.0
24	Conifer-Medium-1Story	90.2	75%	9.0
25	Conifer-Medium-1Story	90.2	85%	9.0
26	Conifer-Medium-1Story	90.2	95%	9.0
27	Conifer-Large-1Story	130.3	5%	13.0

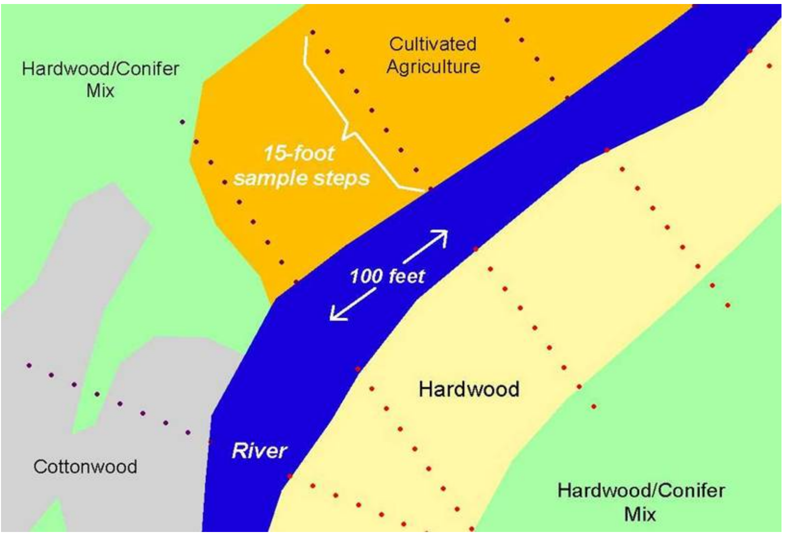
28	Conifer-Large-1Story	130.3	15%	13.0
29	Conifer-Large-1Story	130.3	25%	13.0
30	Conifer-Large-1Story	130.3	35%	13.0
31	Conifer-Large-1Story	130.3	45%	13.0
32	Conifer-Large-1Story	130.3	55%	13.0
33	Conifer-Large-1Story	130.3	65%	13.0
34	Conifer-Large-1Story	130.3	75%	13.0
35	Conifer-Large-1Story	130.3	85%	13.0
36	Conifer-Large-1Story	130.3	95%	13.0
37	Conifer-Xlarge-1Story	160.7	5%	16.1
38	Conifer-Xlarge-1Story	160.7	15%	16.1
39	Conifer-Xlarge-1Story	160.7	25%	16.1
40	Conifer-Xlarge-1Story	160.7	35%	16.1
41	Conifer-Xlarge-1Story	160.7	45%	16.1
42	Conifer-Xlarge-1Story	160.7	55%	16.1
43	Conifer-Xlarge-1Story	160.7	65%	16.1
44	Conifer-Xlarge-1Story	160.7	75%	16.1
45	Conifer-Xlarge-1Story	160.7	85%	16.1
46	Conifer-Xlarge-1Story	160.7	95%	16.1
47	Conifer-Small-2Story	37.4	5%	3.7
48	Conifer-Small-2Story	37.4	15%	3.7
49	Conifer-Small-2Story	37.4	25%	3.7
50	Conifer-Small-2Story	37.4	35%	3.7
51	Conifer-Small-2Story	37.4	45%	3.7
52	Conifer-Small-2Story	37.4	55%	3.7
53	Conifer-Small-2Story	37.4	65%	3.7
54	Conifer-Small-2Story	37.4	75%	3.7
55	Conifer-Small-2Story	37.4	85%	3.7
56	Conifer-Small-2Story	37.4	95%	3.7
57	Conifer-Medium-2Story	90.2	5%	9.0
58	Conifer-Medium-2Story	90.2	15%	9.0
59	Conifer-Medium-2Story	90.2	25%	9.0
60	Conifer-Medium-2Story	90.2	35%	9.0
61	Conifer-Medium-2Story	90.2	45%	9.0
62	Conifer-Medium-2Story	90.2	55%	9.0
63	Conifer-Medium-2Story	90.2	65%	9.0
64	Conifer-Medium-2Story	90.2	75%	9.0
65	Conifer-Medium-2Story	90.2	85%	9.0
66	Conifer-Medium-2Story	90.2	95%	9.0
67	Conifer-Large-2Story	130.3	5%	13.0
68	Conifer-Large-2Story	130.3	15%	13.0
69	Conifer-Large-2Story	130.3	25%	13.0
70	Conifer-Large-2Story	130.3	35%	13.0
71	Conifer-Large-2Story	130.3	45%	13.0
72	Conifer-Large-2Story	130.3	55%	13.0
73	Conifer-Large-2Story	130.3	65%	13.0
74	Conifer-Large-2Story	130.3	75%	13.0
75	Conifer-Large-2Story	130.3	85%	13.0
76	Conifer-Large-2Story	130.3	95%	13.0
77	Conifer-Xlarge-2Story	160.7	5%	16.1
78	Conifer-Xlarge-2Story	160.7	15%	16.1
79	Conifer-Xlarge-2Story	160.7	25%	16.1
80	Conifer-Xlarge-2Story	160.7	35%	16.1
81	Conifer-Xlarge-2Story	160.7	45%	16.1
82	Conifer-Xlarge-2Story	160.7	55%	16.1
83	Conifer-Xlarge-2Story	160.7	65%	16.1
84	Conifer-Xlarge-2Story	160.7	75%	16.1

85	Conifer-Xlarge-2Story	160.7	85%	16.1
86	Conifer-Xlarge-2Story	160.7	95%	16.1
87	Deciduous-Small-1Story	31.0	5%	4.7
88	Deciduous-Small-1Story	31.0	15%	4.7
89	Deciduous-Small-1Story	31.0	25%	4.7
90	Deciduous-Small-1Story	31.0	35%	4.7
91	Deciduous-Small-1Story	31.0	45%	4.7
92	Deciduous-Small-1Story	31.0	55%	4.7
93	Deciduous-Small-1Story	31.0	65%	4.7
94	Deciduous-Small-1Story	31.0	75%	4.7
95	Deciduous-Small-1Story	31.0	85%	4.7
96	Deciduous-Small-1Story	31.0	95%	4.7
97	Deciduous-Medium-1Story	66.8	5%	10.0
98	Deciduous-Medium-1Story	66.8	15%	10.0
99	Deciduous-Medium-1Story	66.8	25%	10.0
100	Deciduous-Medium-1Story	66.8	35%	10.0
101	Deciduous-Medium-1Story	66.8	45%	10.0
102	Deciduous-Medium-1Story	66.8	55%	10.0
103	Deciduous-Medium-1Story	66.8	65%	10.0
104	Deciduous-Medium-1Story	66.8	75%	10.0
105	Deciduous-Medium-1Story	66.8	85%	10.0
106	Deciduous-Medium-1Story	66.8	95%	10.0
107	Deciduous-Large-1Story	87.9	5%	13.2
108	Deciduous-Large-1Story	87.9	15%	13.2
109	Deciduous-Large-1Story	87.9	25%	13.2
110	Deciduous-Large-1Story	87.9	35%	13.2
111	Deciduous-Large-1Story	87.9	45%	13.2
112	Deciduous-Large-1Story	87.9	55%	13.2
113	Deciduous-Large-1Story	87.9	65%	13.2
114	Deciduous-Large-1Story	87.9	75%	13.2
115	Deciduous-Large-1Story	87.9	85%	13.2
116	Deciduous-Large-1Story	87.9	95%	13.2
117	Deciduous-XLarge-1Story	100.6	5%	15.1
118	Deciduous-XLarge-1Story	100.6	15%	15.1
119	Deciduous-XLarge-1Story	100.6	25%	15.1
120	Deciduous-XLarge-1Story	100.6	35%	15.1
121	Deciduous-XLarge-1Story	100.6	45%	15.1
122	Deciduous-XLarge-1Story	100.6	55%	15.1
123	Deciduous-XLarge-1Story	100.6	65%	15.1
124	Deciduous-XLarge-1Story	100.6	75%	15.1
125	Deciduous-XLarge-1Story	100.6	85%	15.1
126	Deciduous-XLarge-1Story	100.6	95%	15.1
127	Deciduous-Small-2Story	31.0	5%	4.7
128	Deciduous-Small-2Story	31.0	15%	4.7
129	Deciduous-Small-2Story	31.0	25%	4.7
130	Deciduous-Small-2Story	31.0	35%	4.7
131	Deciduous-Small-2Story	31.0	45%	4.7
132	Deciduous-Small-2Story	31.0	55%	4.7
133	Deciduous-Small-2Story	31.0	65%	4.7
134	Deciduous-Small-2Story	31.0	75%	4.7
135	Deciduous-Small-2Story	31.0	85%	4.7
136	Deciduous-Small-2Story	31.0	95%	4.7
137	Deciduous-Medium-2Story	66.8	5%	10.0
138	Deciduous-Medium-2Story	66.8	15%	10.0
139	Deciduous-Medium-2Story	66.8	25%	10.0
140	Deciduous-Medium-2Story	66.8	35%	10.0
141	Deciduous-Medium-2Story	66.8	45%	10.0

142	Deciduous-Medium-2Story	66.8	55%	10.0
143	Deciduous-Medium-2Story	66.8	65%	10.0
144	Deciduous-Medium-2Story	66.8	75%	10.0
145	Deciduous-Medium-2Story	66.8	85%	10.0
146	Deciduous-Medium-2Story	66.8	95%	10.0
147	Deciduous-Large-2Story	87.9	5%	13.2
148	Deciduous-Large-2Story	87.9	15%	13.2
149	Deciduous-Large-2Story	87.9	25%	13.2
150	Deciduous-Large-2Story	87.9	35%	13.2
151	Deciduous-Large-2Story	87.9	45%	13.2
152	Deciduous-Large-2Story	87.9	55%	13.2
153	Deciduous-Large-2Story	87.9	65%	13.2
154	Deciduous-Large-2Story	87.9	75%	13.2
155	Deciduous-Large-2Story	87.9	85%	13.2
156	Deciduous-Large-2Story	87.9	95%	13.2
157	Deciduous-XLarge-2Story	100.6	5%	15.1
158	Deciduous-XLarge-2Story	100.6	15%	15.1
159	Deciduous-XLarge-2Story	100.6	25%	15.1
160	Deciduous-XLarge-2Story	100.6	35%	15.1
161	Deciduous-XLarge-2Story	100.6	45%	15.1
162	Deciduous-XLarge-2Story	100.6	55%	15.1
163	Deciduous-XLarge-2Story	100.6	65%	15.1
164	Deciduous-XLarge-2Story	100.6	75%	15.1
165	Deciduous-XLarge-2Story	100.6	85%	15.1
166	Deciduous-XLarge-2Story	100.6	95%	15.1
167	Mixed-Small-1Story	34.2	5%	4.3
168	Mixed-Small-1Story	34.2	15%	4.3
169	Mixed-Small-1Story	34.2	25%	4.3
170	Mixed-Small-1Story	34.2	35%	4.3
171	Mixed-Small-1Story	34.2	45%	4.3
172	Mixed-Small-1Story	34.2	55%	4.3
173	Mixed-Small-1Story	34.2	65%	4.3
174	Mixed-Small-1Story	34.2	75%	4.3
175	Mixed-Small-1Story	34.2	85%	4.3
176	Mixed-Small-1Story	34.2	95%	4.3
177	Mixed-Medium-1Story	78.5	5%	9.8
178	Mixed-Medium-1Story	78.5	15%	9.8
179	Mixed-Medium-1Story	78.5	25%	9.8
180	Mixed-Medium-1Story	78.5	35%	9.8
181	Mixed-Medium-1Story	78.5	45%	9.8
182	Mixed-Medium-1Story	78.5	55%	9.8
183	Mixed-Medium-1Story	78.5	65%	9.8
184	Mixed-Medium-1Story	78.5	75%	9.8
185	Mixed-Medium-1Story	78.5	85%	9.8
186	Mixed-Medium-1Story	78.5	95%	9.8
187	Mixed-Large-1Story	109.1	5%	13.6
188	Mixed-Large-1Story	109.1	15%	13.6
189	Mixed-Large-1Story	109.1	25%	13.6
190	Mixed-Large-1Story	109.1	35%	13.6
191	Mixed-Large-1Story	109.1	45%	13.6
192	Mixed-Large-1Story	109.1	55%	13.6
193	Mixed-Large-1Story	109.1	65%	13.6
194	Mixed-Large-1Story	109.1	75%	13.6
195	Mixed-Large-1Story	109.1	85%	13.6
196	Mixed-Large-1Story	109.1	95%	13.6
197	Mixed-XLarge-1Story	130.6	5%	16.3
198	Mixed-XLarge-1Story	130.6	15%	16.3

199	Mixed-XLarge-1Story	130.6	25%	16.3
200	Mixed-XLarge-1Story	130.6	35%	16.3
201	Mixed-XLarge-1Story	130.6	45%	16.3
202	Mixed-XLarge-1Story	130.6	55%	16.3
203	Mixed-XLarge-1Story	130.6	65%	16.3
204	Mixed-XLarge-1Story	130.6	75%	16.3
205	Mixed-XLarge-1Story	130.6	85%	16.3
206	Mixed-XLarge-1Story	130.6	95%	16.3
207	Mixed-Small-2Story	34.2	5%	4.3
208	Mixed-Small-2Story	34.2	15%	4.3
209	Mixed-Small-2Story	34.2	25%	4.3
210	Mixed-Small-2Story	34.2	35%	4.3
211	Mixed-Small-2Story	34.2	45%	4.3
212	Mixed-Small-2Story	34.2	55%	4.3
213	Mixed-Small-2Story	34.2	65%	4.3
214	Mixed-Small-2Story	34.2	75%	4.3
215	Mixed-Small-2Story	34.2	85%	4.3
216	Mixed-Small-2Story	34.2	95%	4.3
217	Mixed-Medium-2Story	78.5	5%	9.8
218	Mixed-Medium-2Story	78.5	15%	9.8
219	Mixed-Medium-2Story	78.5	25%	9.8
220	Mixed-Medium-2Story	78.5	35%	9.8
221	Mixed-Medium-2Story	78.5	45%	9.8
222	Mixed-Medium-2Story	78.5	55%	9.8
223	Mixed-Medium-2Story	78.5	65%	9.8
224	Mixed-Medium-2Story	78.5	75%	9.8
225	Mixed-Medium-2Story	78.5	85%	9.8
226	Mixed-Medium-2Story	78.5	95%	9.8
227	Mixed-Large-2Story	109.1	5%	13.6
228	Mixed-Large-2Story	109.1	15%	13.6
229	Mixed-Large-2Story	109.1	25%	13.6
230	Mixed-Large-2Story	109.1	35%	13.6
231	Mixed-Large-2Story	109.1	45%	13.6
232	Mixed-Large-2Story	109.1	55%	13.6
233	Mixed-Large-2Story	109.1	65%	13.6
234	Mixed-Large-2Story	109.1	75%	13.6
235	Mixed-Large-2Story	109.1	85%	13.6
236	Mixed-Large-2Story	109.1	95%	13.6
237	Mixed-XLarge-2Story	130.6	5%	16.3
238	Mixed-XLarge-2Story	130.6	15%	16.3
239	Mixed-XLarge-2Story	130.6	25%	16.3
240	Mixed-XLarge-2Story	130.6	35%	16.3
241	Mixed-XLarge-2Story	130.6	45%	16.3
242	Mixed-XLarge-2Story	130.6	55%	16.3
243	Mixed-XLarge-2Story	130.6	65%	16.3
244	Mixed-XLarge-2Story	130.6	75%	16.3
245	Mixed-XLarge-2Story	130.6	85%	16.3
246	Mixed-XLarge-2Story	130.6	95%	16.3
247	Urban	25.0	100%	0.0

The digitized/classified near stream land cover layer was sampled using TTools. **Figure 3-12** illustrates how TTools samples near stream land cover. For every stream data node (i.e., every 100 feet along the stream channel centerline), beginning at the edge of the stream channel, sampling occurs perpendicular to the stream at eight user-defined intervals (i.e., every 15 feet). This sampling occurs for both stream banks for every stream data node.



***Near Stream Land Cover Sampling** is performed at each data node and extends in the transverse direction at a user-defined interval (the default is every 15 feet). The user also has the option of sampling starting at the stream node or outside of the channel edge.*

Figure 3-12. *Automated sampling of near stream land cover data using TTools.*

3.5.3 Near Stream Land Cover - Potential Condition Development

The process of developing potential near stream land cover data should start with definitions and a discussion of the context in which it is used in the TMDL methodology. **Potential near stream land cover** is that which can grow and reproduce on a site given plant biology, site elevation, soil characteristics and local climate. Potential near stream land cover does not include considerations for resource management, human use or other human disturbance. Natural disturbance regimes (i.e., fire, disease, wind-throw, etc.) are also not accounted for in this definition. There is an assumption that despite natural disturbance, potential near stream land cover types (as defined) will survive and recover from a natural disturbance event.

The TMDL methodology is developed under the Oregon stream temperature standard where a condition of "no anthropogenic warming" is allowed. In simple terms, a condition is targeted where human related stream warming is minimized. Since near stream land cover is a controlling factor in stream temperature regimes, the condition and health of land cover is considered a primary parameter considered in the TMDL. Removal of human disturbance from near stream land cover is a pathway for compliance with Oregon's stream temperature standard. **Potential near stream land cover**, by definition, is the condition that meets Oregon's stream temperature standard, and is therefore, targeted in the TMDL

Rules for Developing Potential Near Stream Land cover

1. Barren land cover types that can grow land cover (i.e., clearcut areas, embankments, forest roads, etc.) are assigned the nearest adjacent non-developed land cover type.
2. Developed land cover types that can grow land cover are assigned the nearest adjacent non-developed land cover type.
3. Pastures, cultivated fields and lawn land cover types are assigned the nearest adjacent non-developed land cover type.
4. Instream and channel structures (i.e., dikes, canals, etc.) land cover types that can grow land cover are assigned the nearest adjacent non-developed land cover type.
5. Water and barren rock cannot grow land cover and are not changed.
6. Wetland land cover type is not changed.
7. The conifer land cover type is assumed to grow to undisturbed potential height and density.
8. The hardwood land cover type is assumed to grow to undisturbed potential height and density.
9. The mixed conifer/hardwood land cover type is assumed to grow to undisturbed potential height and density.

Potential tree height was derived for conifer, mixed conifer/hardwood, and hardwood stands. Tree height targets were based on growth curves analysis and observed ranges of tree heights in the North Coast Subbasins (Whitney 1997, **Figure 3-15**). Potential vegetation density is assumed to be 90% for all tree species.

Table 3-8 displays the potential near stream land cover characteristics that were applied, based on the existing near stream land cover characteristics.

Table 3-7. Potential Tree Heights

Species	**Average Height**	**Age**
Douglas Fir	160 to 180 feet	80 years
Western Hemlock	140 feet	
Western Red Cedar	120 to 140 feet	
Sitka Spruce	140 feet	
Red Alder	100 feet	
Bigleaf Maple	100 feet	

Land Cover Type	**Dominant Tree Species and Mature Tree Height**	***Targeted Height***
Coniferous	Douglas Fir - 175 feet	*175 feet*
Mixed Deciduous and Conifer	50% Douglas Fir – 175 feet Western Hemlock – 140 feet Western Red Cedar – 140 feet Sitka Spruce – 140 feet	*125 feet*
	50% Red Alder - 100 feet Bigleaf Maple - 100 feet	
Deciduous	Red Alder - 100 feet Bigleaf Maple - 100 feet	*100 feet*

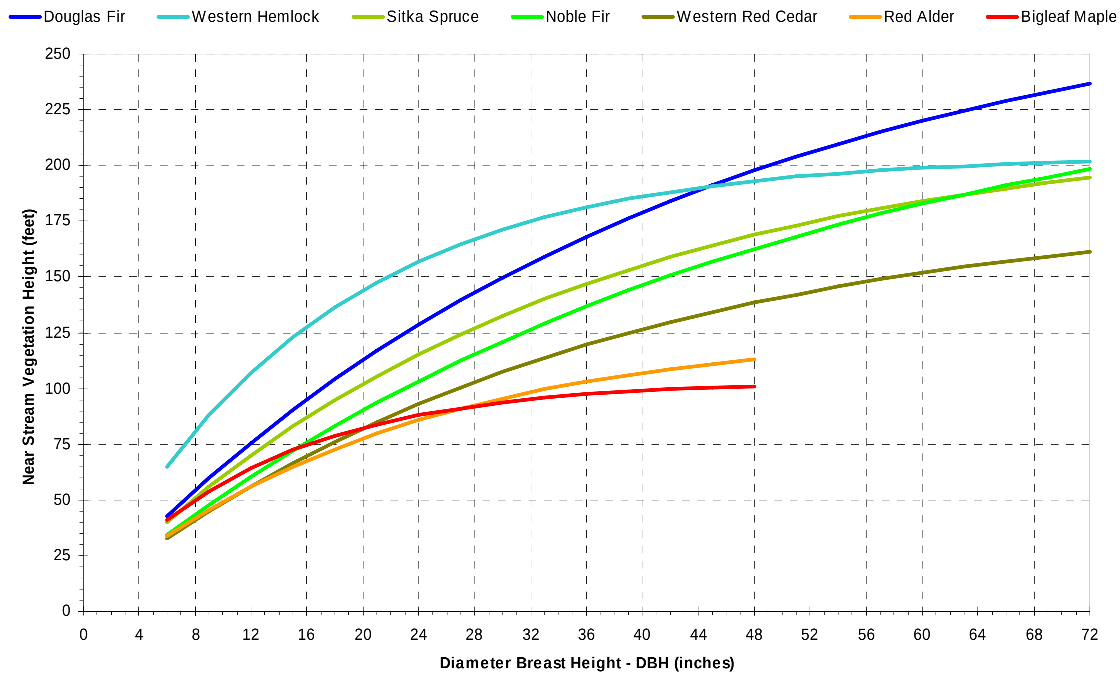


Figure 3-13. *Tree Height as a Function of Diameter Breast Height (DBH) (Hann, 1997 and Richards 1959).*

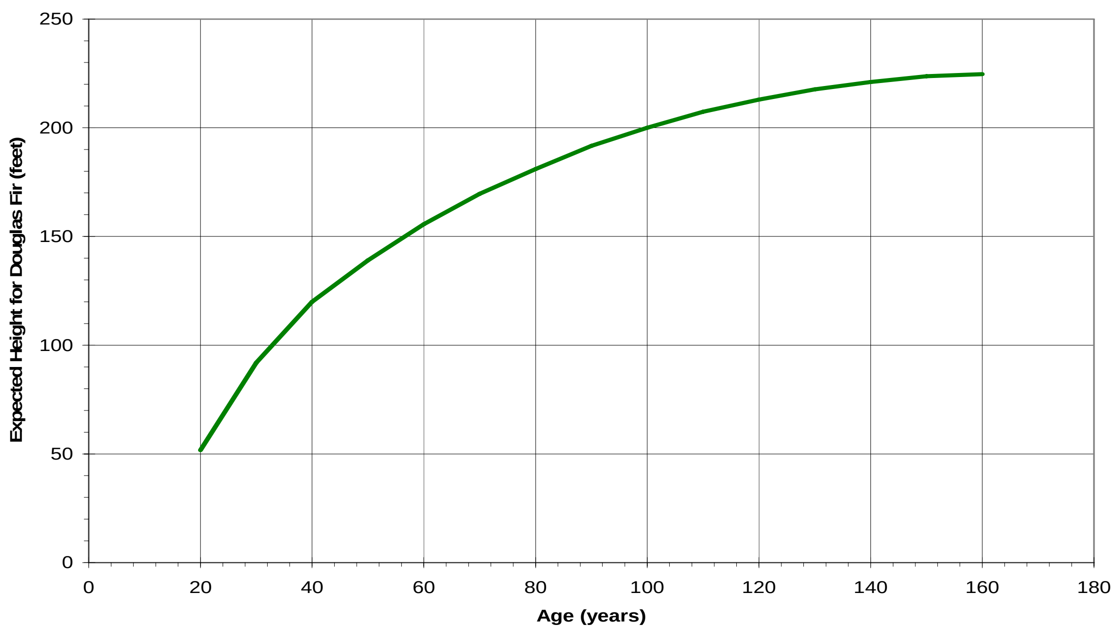


Figure 3-14. *Expected Tree Height for Douglas Fir as a Function of Stand Age – Site Quality I (McArdle and Meyer, 1961).*

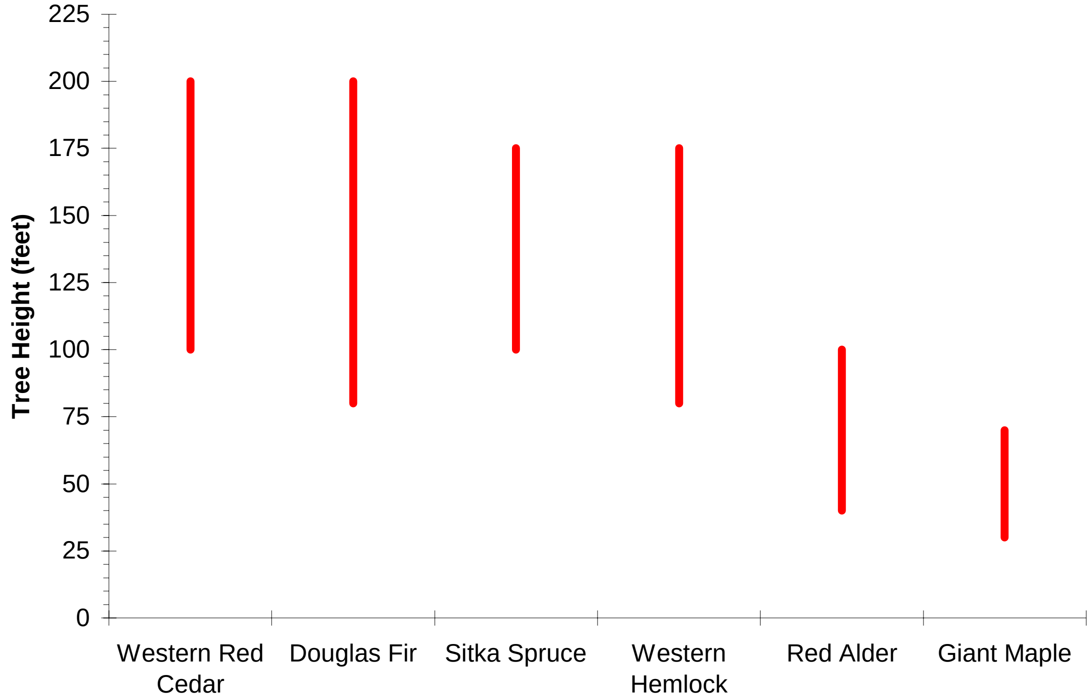


Figure 3-15. *Tree Heights for Dominant Tree Species in the North Oregon Coast (Whitney, 1997).*

Table 3-8. Near Stream Land Cover Codes used in Classification Process.

Code	Source	Existing Near Stream Land Cover	Potential Near Stream Land Cover
500	DEQ/PSU	Water	Water
601	DEQ/PSU	Pastures/Cultivated Field/lawn	Nearest Neighbor
400	DEQ/PSU	Barren	Nearest Neighbor
1013	DEQ/PSU	Barren - Clearcut	Large Conifer
300	DEQ/PSU	Barren - Road	Nearest Neighbor
200	DEQ/PSU	Barren - Railroad	Nearest Neighbor
932	DEQ/PSU	L. Mixed Con/Hard (50-100% CC)	L. Mixed Con/Hard
922	DEQ/PSU	S. Mixed Con/Hard (50-100% CC)	L. Mixed Con/Hard
931	DEQ/PSU	L. Mixed Con/Hard (<50% CC)	L. Mixed Con/Hard
921	DEQ/PSU	S. Mixed Con/Hard (<50% CC)	L. Mixed Con/Hard
832	DEQ/PSU	Large Hardwood (50-100% CC)	Large Hardwood
822	DEQ/PSU	Small Hardwood (50-100% CC)	Large Hardwood
831	DEQ/PSU	Large Hardwood (<50% CC)	Large Hardwood
821	DEQ/PSU	Small Hardwood (<50% CC)	Large Hardwood
1032	DEQ/PSU	Large Conifer	Large Conifer
1022	DEQ/PSU	Small Conifer	Large Conifer
1031	DEQ/PSU	Large Conifer	Large Conifer
1021	DEQ/PSU	Small Conifer	Large Conifer
902	DEQ/PSU	Tree Farm	L. Mixed Con/Hard
1012	DEQ/PSU	Conifer Regeneration Dense	Large Conifer
1011	DEQ/PSU	Conifer Regeneration Sparse	Large Conifer
700	DEQ/PSU	Shrubs	Nearest Neighbor
600	DEQ/PSU	Grasses - upland	Nearest Neighbor
901	DEQ/PSU	Dike	Nearest Neighbor
100	DEQ/PSU	Structure (house)	Nearest Neighbor
900	DEQ/PSU	Hatchery (or similar ponds)	Nearest Neighbor
903	DEQ/PSU	Wetland	Wetland
1	WODIP	Water	Water
2	WODIP	Agriculture	Nearest Neighbor
3	WODIP	Non_Forest	Nearest Neighbor
4	WODIP	Grass/Bushes	Nearest Neighbor
5	WODIP	Other	Nearest Neighbor
6	WODIP	Clearcut	Large Conifer
7	WODIP	Conifer-Small-1Story	Large Conifer
8	WODIP	Conifer-Small-1Story	Large Conifer
9	WODIP	Conifer-Small-1Story	Large Conifer
10	WODIP	Conifer-Small-1Story	Large Conifer
11	WODIP	Conifer-Small-1Story	Large Conifer
12	WODIP	Conifer-Small-1Story	Large Conifer
13	WODIP	Conifer-Small-1Story	Large Conifer
14	WODIP	Conifer-Small-1Story	Large Conifer
15	WODIP	Conifer-Small-1Story	Large Conifer
16	WODIP	Conifer-Small-1Story	Large Conifer

17	WODIP	Conifer-Medium-1Story	Large Conifer
18	WODIP	Conifer-Medium-1Story	Large Conifer
19	WODIP	Conifer-Medium-1Story	Large Conifer
20	WODIP	Conifer-Medium-1Story	Large Conifer
21	WODIP	Conifer-Medium-1Story	Large Conifer
22	WODIP	Conifer-Medium-1Story	Large Conifer
23	WODIP	Conifer-Medium-1Story	Large Conifer
24	WODIP	Conifer-Medium-1Story	Large Conifer
25	WODIP	Conifer-Medium-1Story	Large Conifer
26	WODIP	Conifer-Medium-1Story	Large Conifer
27	WODIP	Conifer-Large-1Story	Large Conifer
28	WODIP	Conifer-Large-1Story	Large Conifer
29	WODIP	Conifer-Large-1Story	Large Conifer
30	WODIP	Conifer-Large-1Story	Large Conifer
31	WODIP	Conifer-Large-1Story	Large Conifer
32	WODIP	Conifer-Large-1Story	Large Conifer
33	WODIP	Conifer-Large-1Story	Large Conifer
34	WODIP	Conifer-Large-1Story	Large Conifer
35	WODIP	Conifer-Large-1Story	Large Conifer
36	WODIP	Conifer-Large-1Story	Large Conifer
37	WODIP	Conifer-Xlarge-1Story	Large Conifer
38	WODIP	Conifer-Xlarge-1Story	Large Conifer
39	WODIP	Conifer-Xlarge-1Story	Large Conifer
40	WODIP	Conifer-Xlarge-1Story	Large Conifer
41	WODIP	Conifer-Xlarge-1Story	Large Conifer
42	WODIP	Conifer-Xlarge-1Story	Large Conifer
43	WODIP	Conifer-Xlarge-1Story	Large Conifer
44	WODIP	Conifer-Xlarge-1Story	Large Conifer
45	WODIP	Conifer-Xlarge-1Story	Large Conifer
46	WODIP	Conifer-Xlarge-1Story	Large Conifer
47	WODIP	Conifer-Small-2Story	Large Conifer
48	WODIP	Conifer-Small-2Story	Large Conifer
49	WODIP	Conifer-Small-2Story	Large Conifer
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52	WODIP	Conifer-Small-2Story	Large Conifer
53	WODIP	Conifer-Small-2Story	Large Conifer
54	WODIP	Conifer-Small-2Story	Large Conifer
55	WODIP	Conifer-Small-2Story	Large Conifer
56	WODIP	Conifer-Small-2Story	Large Conifer
57	WODIP	Conifer-Medium-2Story	Large Conifer
58	WODIP	Conifer-Medium-2Story	Large Conifer
59	WODIP	Conifer-Medium-2Story	Large Conifer
60	WODIP	Conifer-Medium-2Story	Large Conifer
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62	WODIP	Conifer-Medium-2Story	Large Conifer
63	WODIP	Conifer-Medium-2Story	Large Conifer
64	WODIP	Conifer-Medium-2Story	Large Conifer

65	WODIP	Conifer-Medium-2Story	Large Conifer
66	WODIP	Conifer-Medium-2Story	Large Conifer
67	WODIP	Conifer-Large-2Story	Large Conifer
68	WODIP	Conifer-Large-2Story	Large Conifer
69	WODIP	Conifer-Large-2Story	Large Conifer
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75	WODIP	Conifer-Large-2Story	Large Conifer
76	WODIP	Conifer-Large-2Story	Large Conifer
77	WODIP	Conifer-Xlarge-2Story	Large Conifer
78	WODIP	Conifer-Xlarge-2Story	Large Conifer
79	WODIP	Conifer-Xlarge-2Story	Large Conifer
80	WODIP	Conifer-Xlarge-2Story	Large Conifer
81	WODIP	Conifer-Xlarge-2Story	Large Conifer
82	WODIP	Conifer-Xlarge-2Story	Large Conifer
83	WODIP	Conifer-Xlarge-2Story	Large Conifer
84	WODIP	Conifer-Xlarge-2Story	Large Conifer
85	WODIP	Conifer-Xlarge-2Story	Large Conifer
86	WODIP	Conifer-Xlarge-2Story	Large Conifer
87	WODIP	Deciduous-Small-1Story	Large Deciduous
88	WODIP	Deciduous-Small-1Story	Large Deciduous
89	WODIP	Deciduous-Small-1Story	Large Deciduous
90	WODIP	Deciduous-Small-1Story	Large Deciduous
91	WODIP	Deciduous-Small-1Story	Large Deciduous
92	WODIP	Deciduous-Small-1Story	Large Deciduous
93	WODIP	Deciduous-Small-1Story	Large Deciduous
94	WODIP	Deciduous-Small-1Story	Large Deciduous
95	WODIP	Deciduous-Small-1Story	Large Deciduous
96	WODIP	Deciduous-Small-1Story	Large Deciduous
97	WODIP	Deciduous-Medium-1Story	Large Deciduous
98	WODIP	Deciduous-Medium-1Story	Large Deciduous
99	WODIP	Deciduous-Medium-1Story	Large Deciduous
100	WODIP	Deciduous-Medium-1Story	Large Deciduous
101	WODIP	Deciduous-Medium-1Story	Large Deciduous
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115	WODIP	Deciduous-Large-1Story	Large Deciduous
116	WODIP	Deciduous-Large-1Story	Large Deciduous
117	WODIP	Deciduous-XLarge-1Story	Large Deciduous
118	WODIP	Deciduous-XLarge-1Story	Large Deciduous
119	WODIP	Deciduous-XLarge-1Story	Large Deciduous
120	WODIP	Deciduous-XLarge-1Story	Large Deciduous
121	WODIP	Deciduous-XLarge-1Story	Large Deciduous
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124	WODIP	Deciduous-XLarge-1Story	Large Deciduous
125	WODIP	Deciduous-XLarge-1Story	Large Deciduous
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132	WODIP	Deciduous-Small-2Story	Large Deciduous
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157	WODIP	Deciduous-XLarge-2Story	Large Deciduous
158	WODIP	Deciduous-XLarge-2Story	Large Deciduous
159	WODIP	Deciduous-XLarge-2Story	Large Deciduous
160	WODIP	Deciduous-XLarge-2Story	Large Deciduous

161	WODIP	Deciduous-XLarge-2Story	Large Deciduous
162	WODIP	Deciduous-XLarge-2Story	Large Deciduous
163	WODIP	Deciduous-XLarge-2Story	Large Deciduous
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165	WODIP	Deciduous-XLarge-2Story	Large Deciduous
166	WODIP	Deciduous-XLarge-2Story	Large Deciduous
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169	WODIP	Mixed-Small-1Story	Large Mixed
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174	WODIP	Mixed-Small-1Story	Large Mixed
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195	WODIP	Mixed-Large-1Story	Large Mixed
196	WODIP	Mixed-Large-1Story	Large Mixed
197	WODIP	Mixed-XLarge-1Story	Large Mixed
198	WODIP	Mixed-XLarge-1Story	Large Mixed
199	WODIP	Mixed-XLarge-1Story	Large Mixed
200	WODIP	Mixed-XLarge-1Story	Large Mixed
201	WODIP	Mixed-XLarge-1Story	Large Mixed
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203	WODIP	Mixed-XLarge-1Story	Large Mixed
204	WODIP	Mixed-XLarge-1Story	Large Mixed
205	WODIP	Mixed-XLarge-1Story	Large Mixed
206	WODIP	Mixed-XLarge-1Story	Large Mixed
207	WODIP	Mixed-Small-2Story	Large Mixed
208	WODIP	Mixed-Small-2Story	Large Mixed

209	WODIP	Mixed-Small-2Story	Large Mixed
210	WODIP	Mixed-Small-2Story	Large Mixed
211	WODIP	Mixed-Small-2Story	Large Mixed
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213	WODIP	Mixed-Small-2Story	Large Mixed
214	WODIP	Mixed-Small-2Story	Large Mixed
215	WODIP	Mixed-Small-2Story	Large Mixed
216	WODIP	Mixed-Small-2Story	Large Mixed
217	WODIP	Mixed-Medium-2Story	Large Mixed
218	WODIP	Mixed-Medium-2Story	Large Mixed
219	WODIP	Mixed-Medium-2Story	Large Mixed
220	WODIP	Mixed-Medium-2Story	Large Mixed
221	WODIP	Mixed-Medium-2Story	Large Mixed
222	WODIP	Mixed-Medium-2Story	Large Mixed
223	WODIP	Mixed-Medium-2Story	Large Mixed
224	WODIP	Mixed-Medium-2Story	Large Mixed
225	WODIP	Mixed-Medium-2Story	Large Mixed
226	WODIP	Mixed-Medium-2Story	Large Mixed
227	WODIP	Mixed-Large-2Story	Large Mixed
228	WODIP	Mixed-Large-2Story	Large Mixed
229	WODIP	Mixed-Large-2Story	Large Mixed
230	WODIP	Mixed-Large-2Story	Large Mixed
231	WODIP	Mixed-Large-2Story	Large Mixed
232	WODIP	Mixed-Large-2Story	Large Mixed
233	WODIP	Mixed-Large-2Story	Large Mixed
234	WODIP	Mixed-Large-2Story	Large Mixed
235	WODIP	Mixed-Large-2Story	Large Mixed
236	WODIP	Mixed-Large-2Story	Large Mixed
237	WODIP	Mixed-XLarge-2Story	Large Mixed
238	WODIP	Mixed-XLarge-2Story	Large Mixed
239	WODIP	Mixed-XLarge-2Story	Large Mixed
240	WODIP	Mixed-XLarge-2Story	Large Mixed
241	WODIP	Mixed-XLarge-2Story	Large Mixed
242	WODIP	Mixed-XLarge-2Story	Large Mixed
243	WODIP	Mixed-XLarge-2Story	Large Mixed
244	WODIP	Mixed-XLarge-2Story	Large Mixed
245	WODIP	Mixed-XLarge-2Story	Large Mixed
246	WODIP	Mixed-XLarge-2Story	Large Mixed
247	WODIP	Urban	Nearest Neighbor

3.5.4 Results - 2-Deminsional Near Stream Land Cover Height

Existing land cover was sampled for the all of the streams[2] shown in **Figure 3-16**. The current condition and developed potential near stream land cover condition are plotted in **Figures 3-17** to **3-34**.

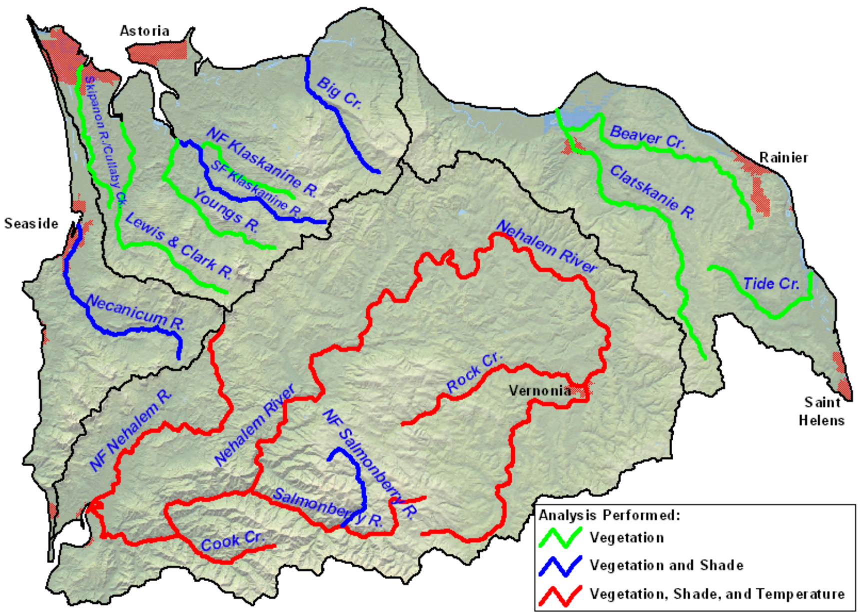


Figure 3-16. *Locations where near stream land cover (vegetation) was digitized and sampled.*

Near stream land cover was mapped and sampled on the following streams:

- Nehalem River
- North Fork Nehalem River
- Rock Creek
- Salmonberry River
- North Fork Salmonberry River
- Cook Creek
- Necanicum River
- Cullaby Creek
- Skipanon River
- Lewis and Clark River
- Youngs River
- Klaskanine River
- South Fork Klaskanine River
- North Fork Klaskanine River
- Big Creek
- Clatskanie River
- Beaver Creek
- Tide Creek

[2] Portland State University has digitized and classified near stream land cover for all streams within the Nehalem River subbasin. DEQ incorporated WODIP classifications, sampled, and developed potentials for the streams listed in the table.

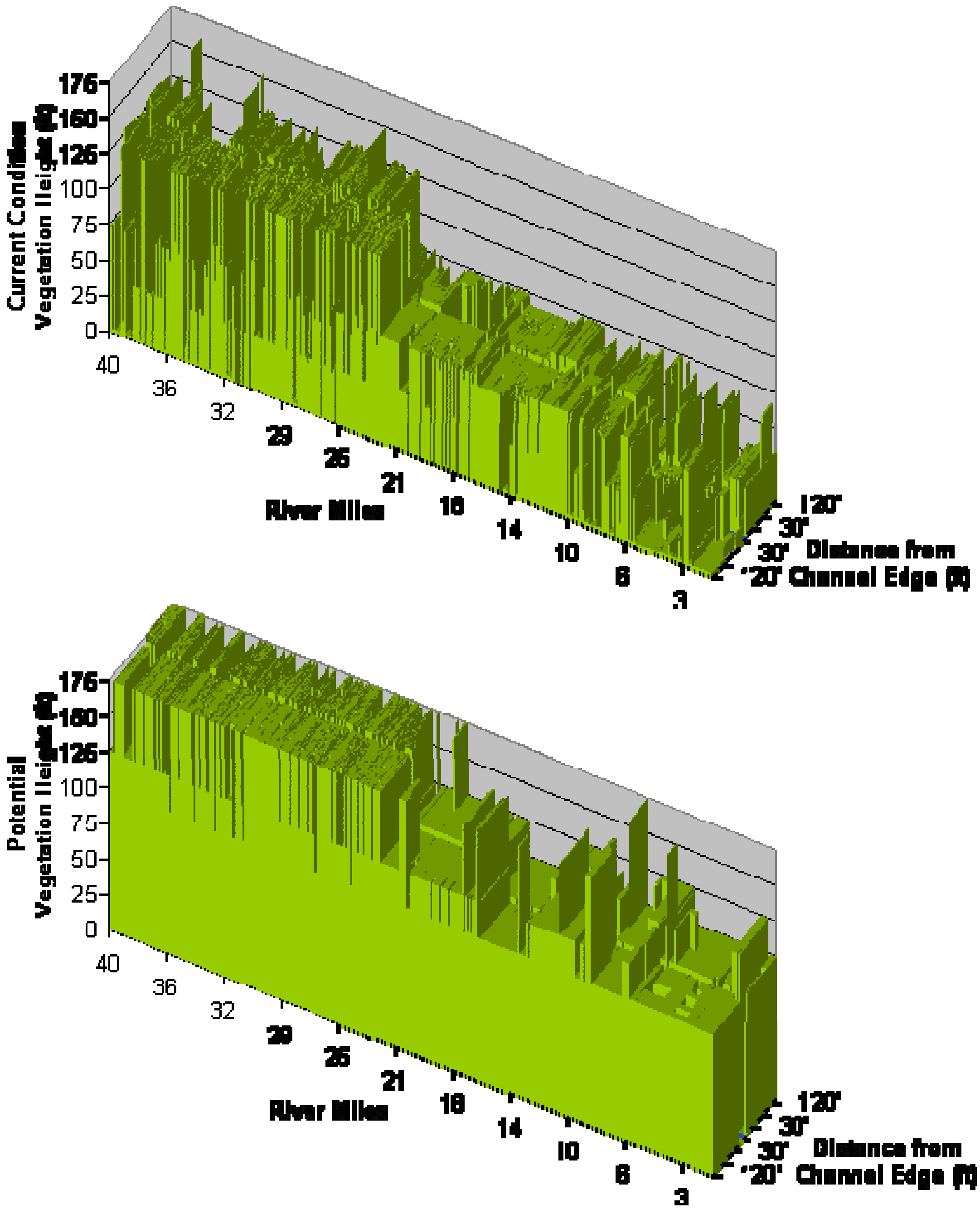


Figure 3-17. *Nehalem River Near Stream Land Cover Heights (River Miles 0 to 40)*

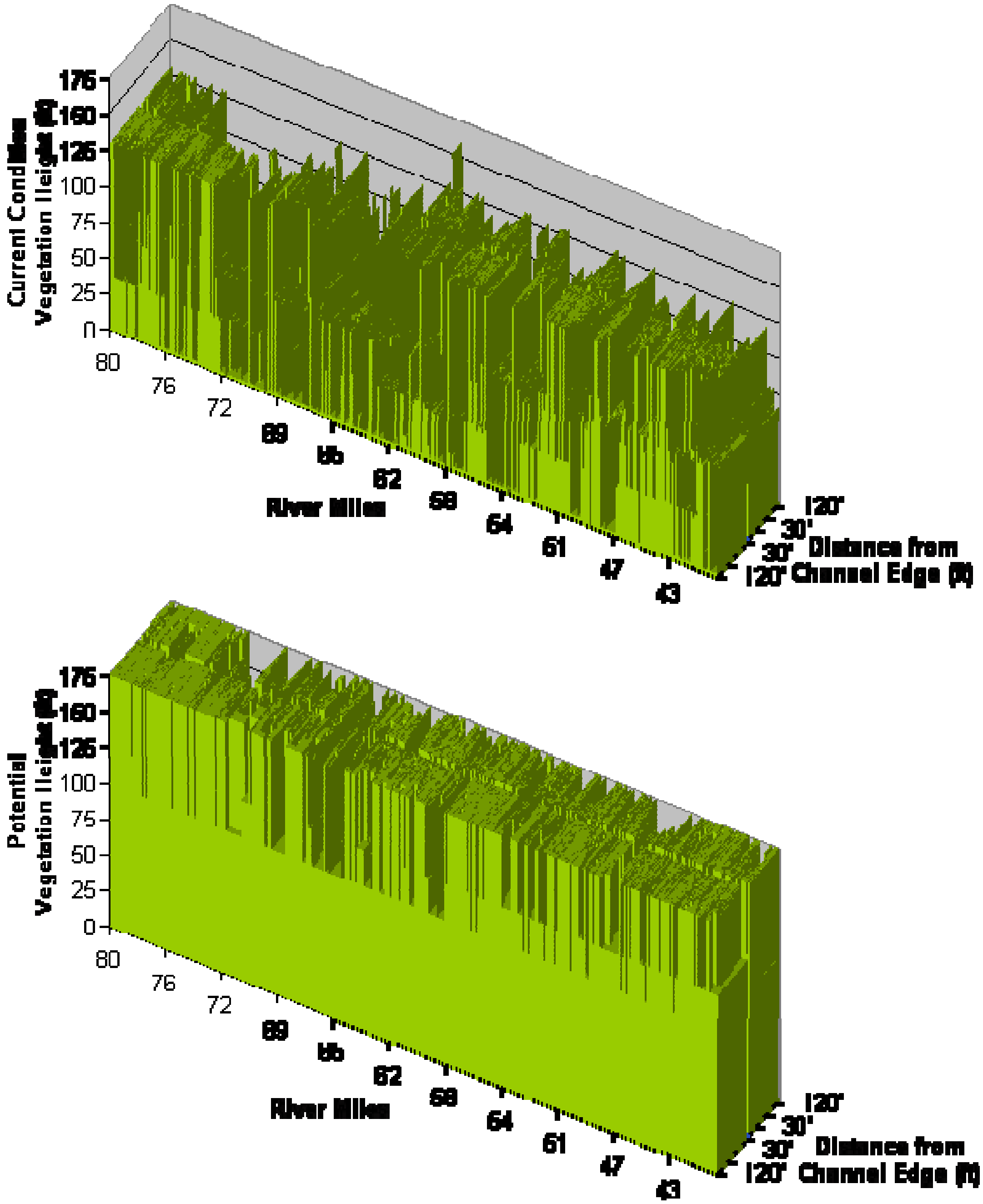


Figure 3-18. *Nehalem River Near Stream Land Cover Heights (River Miles 40 to 80)*

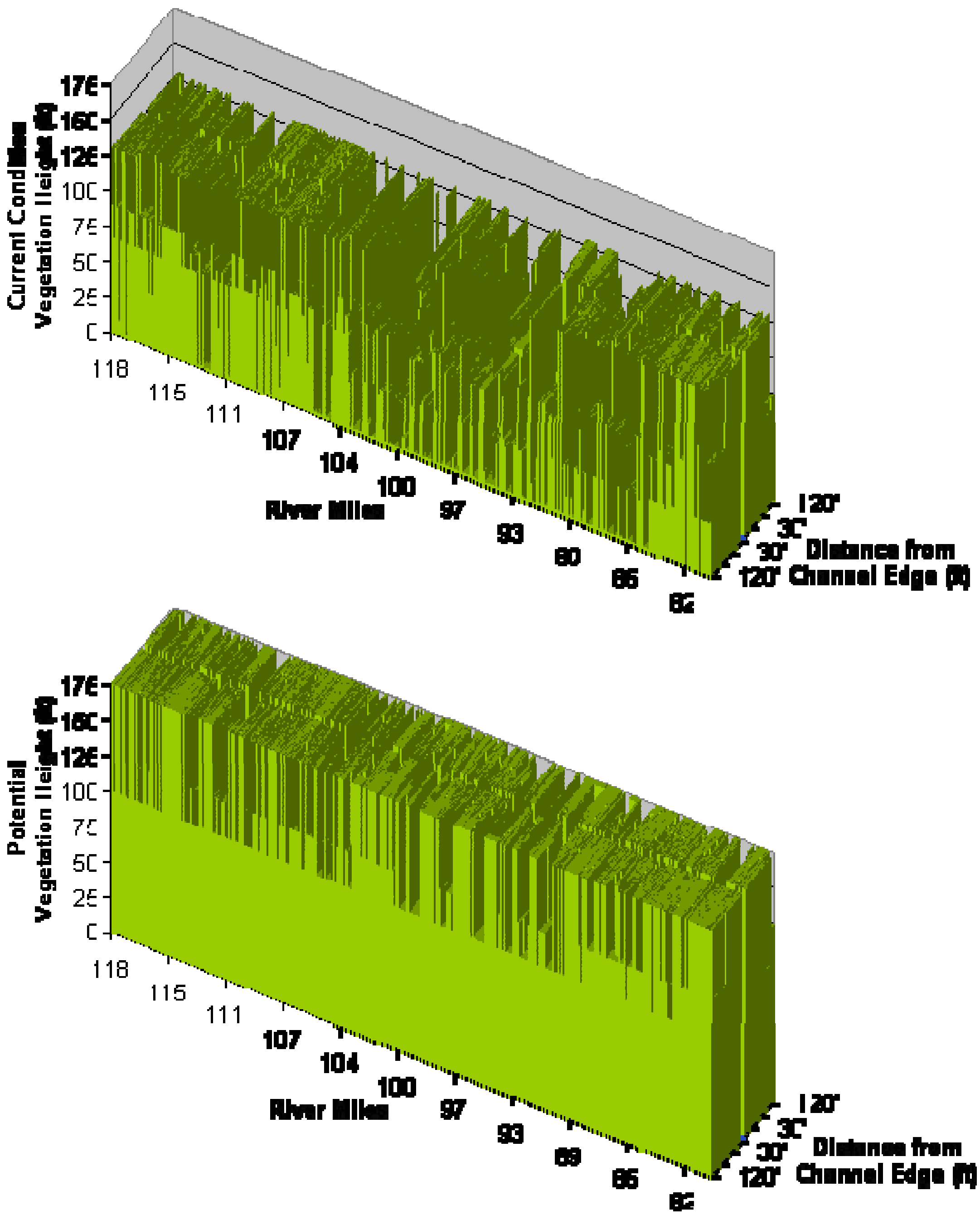


Figure 3-19. *Nehalem River Near Stream Land Cover Heights (River Miles 80 to 118)*

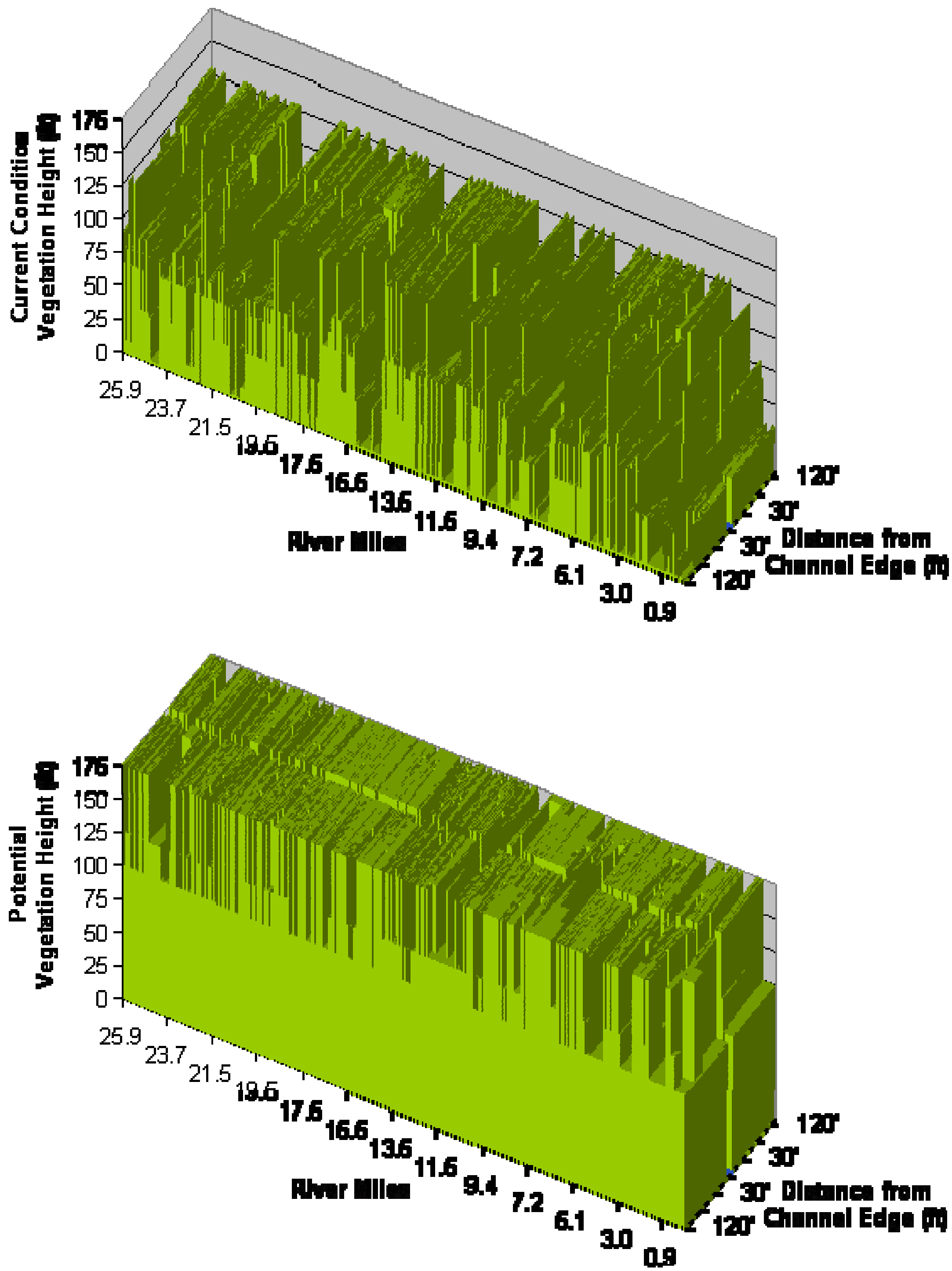
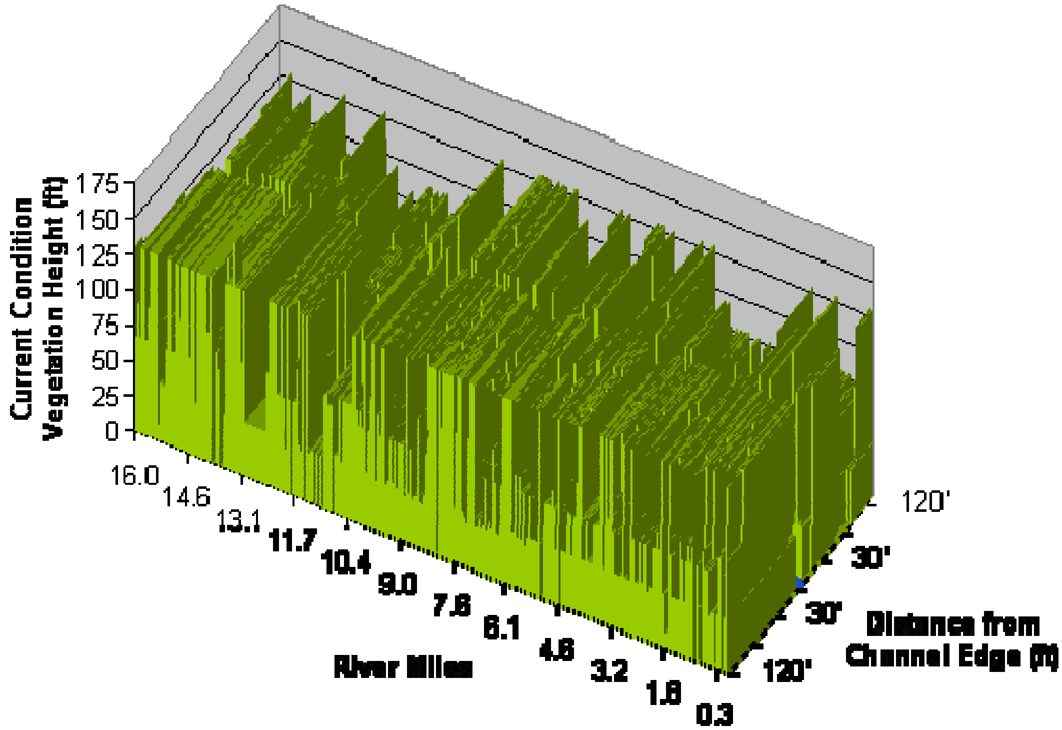


Figure 3-20. *Rock Creek Near Stream Land Cover Heights (Nehalem River Subbasin)*



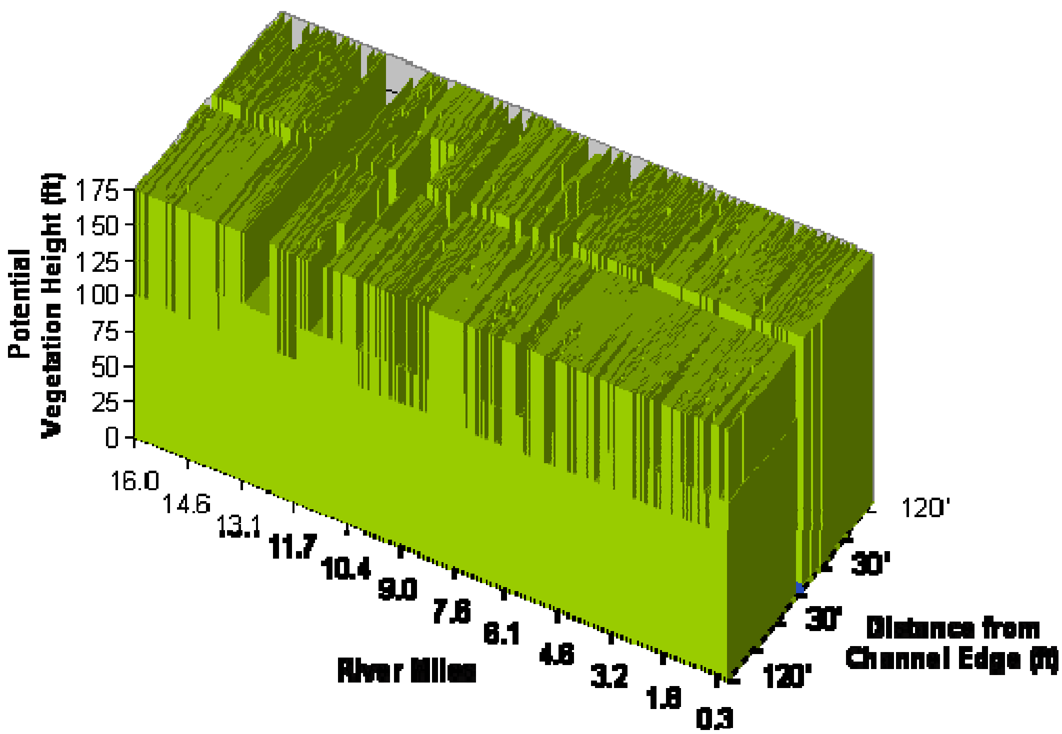


Figure 3-21. *Salmonberry River Near Stream Land Cover Heights (Nehalem River Subbasin)*

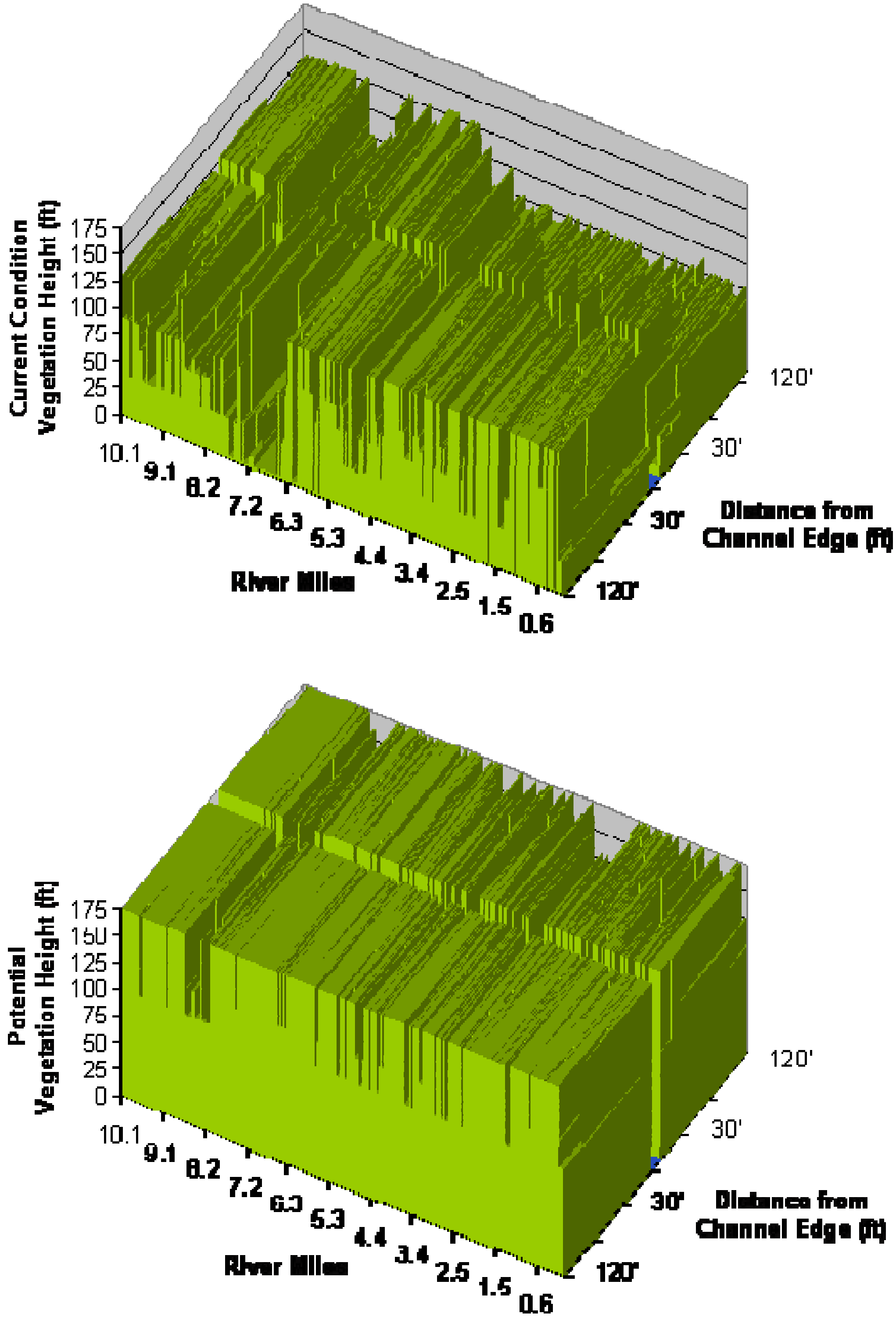


Figure 3-22. *North Fork Salmonberry River Near Stream Land Cover Heights (Nehalem River Subbasin)*

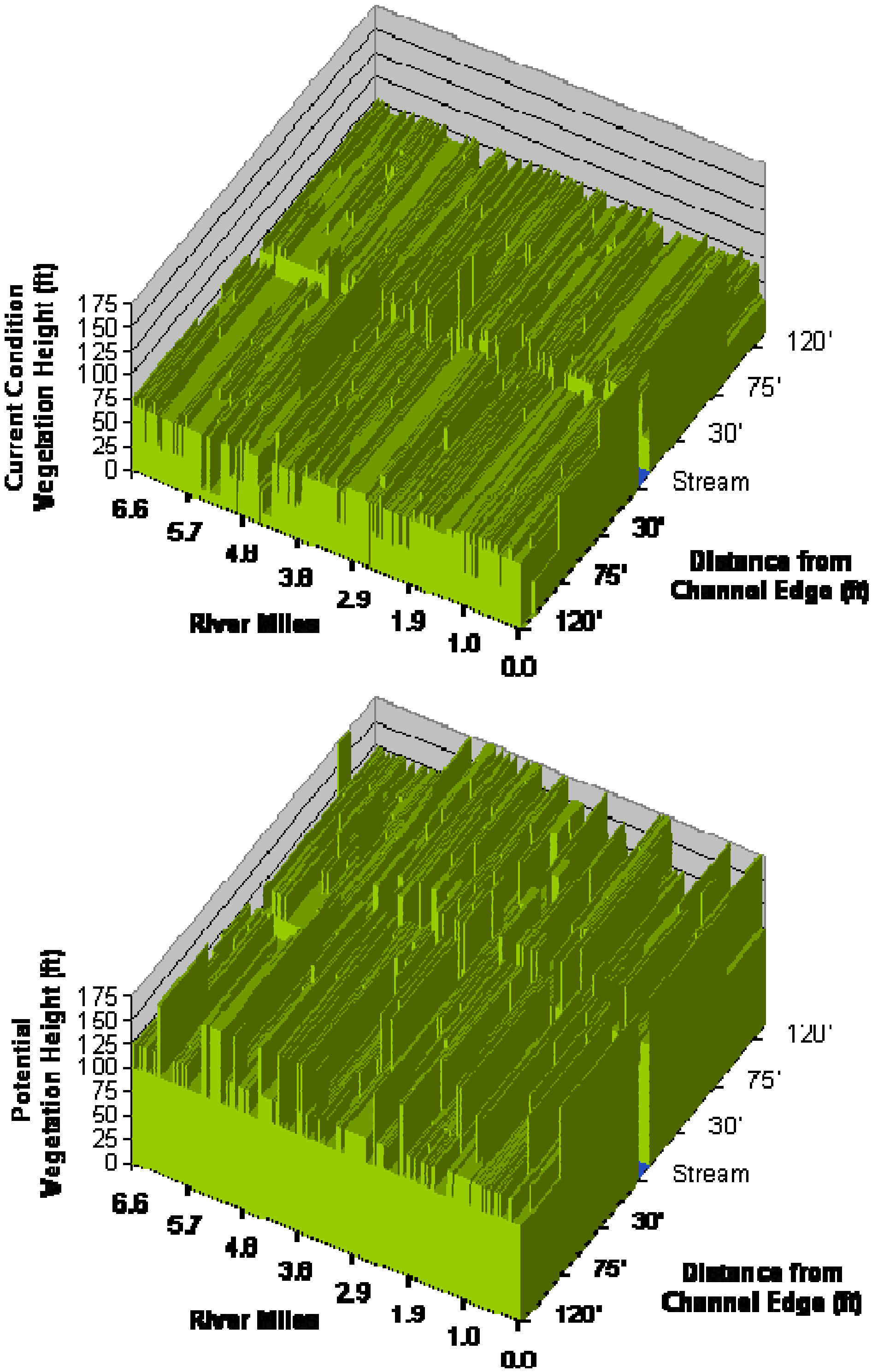


Figure 3-23. *Cook Creek Near Stream Land Cover Heights (Nehalem River Subbasin)*

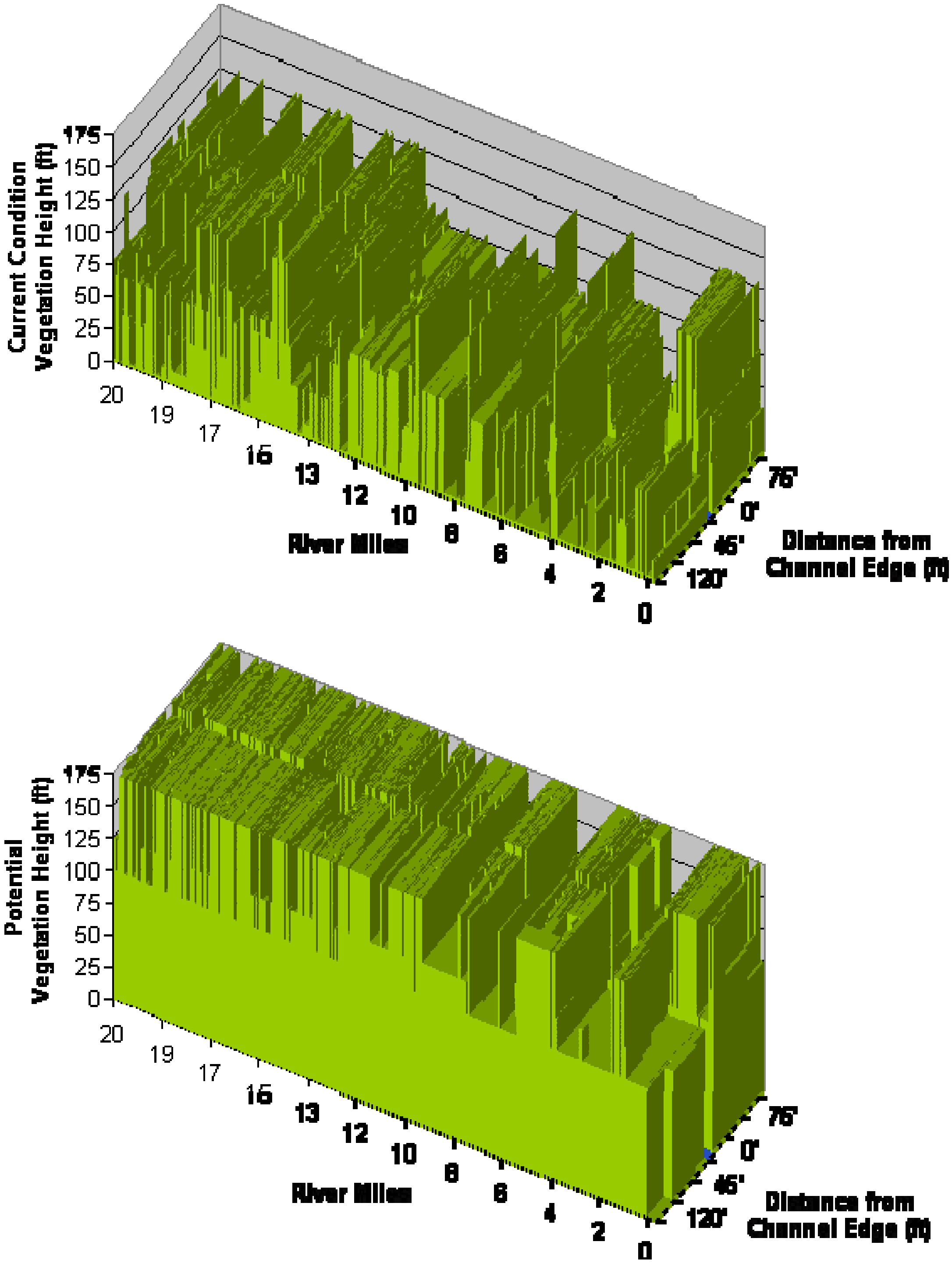


Figure 3-24. *North Fork Nehalem River Near Stream Land Cover Heights (Nehalem River Subbasin)*

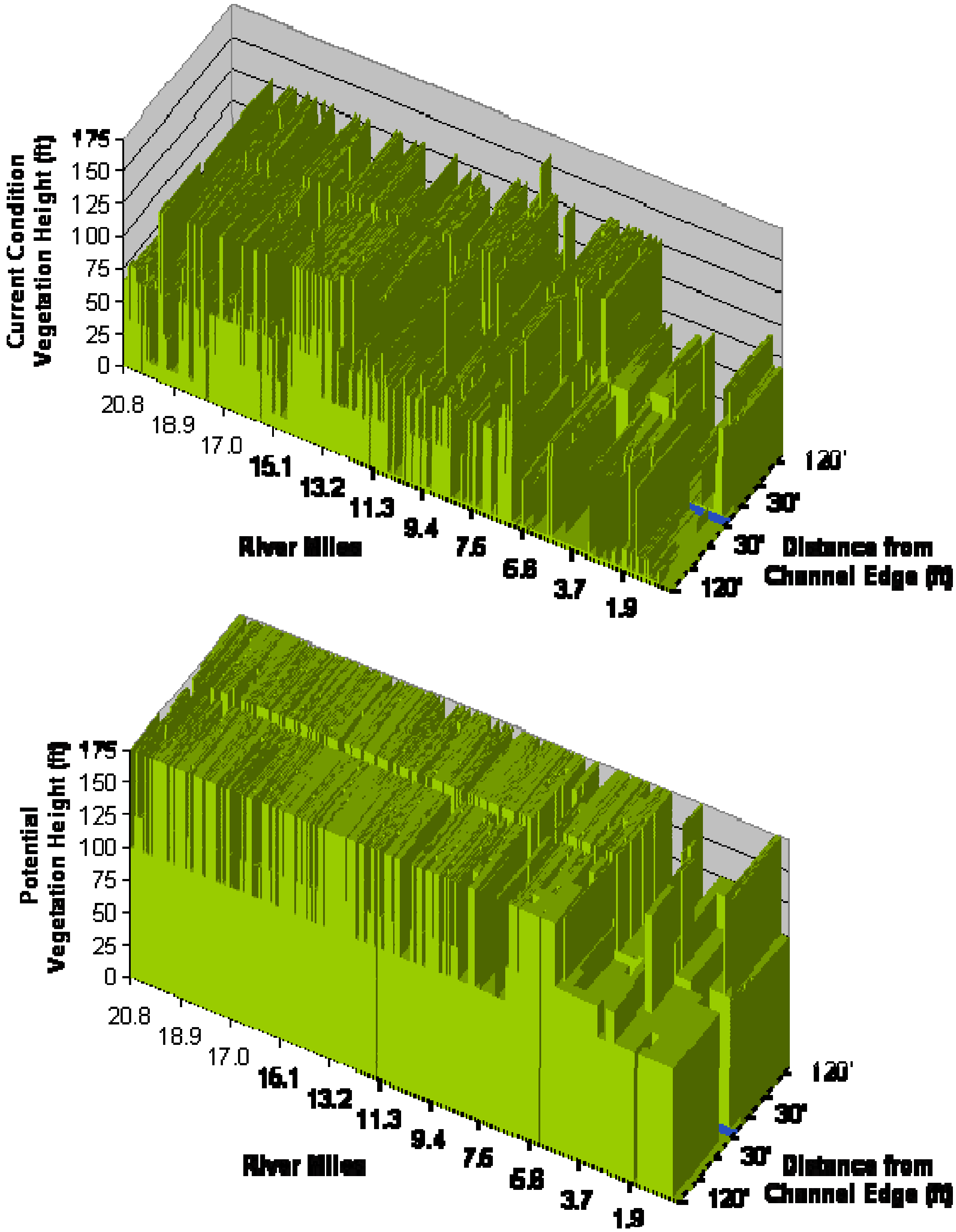
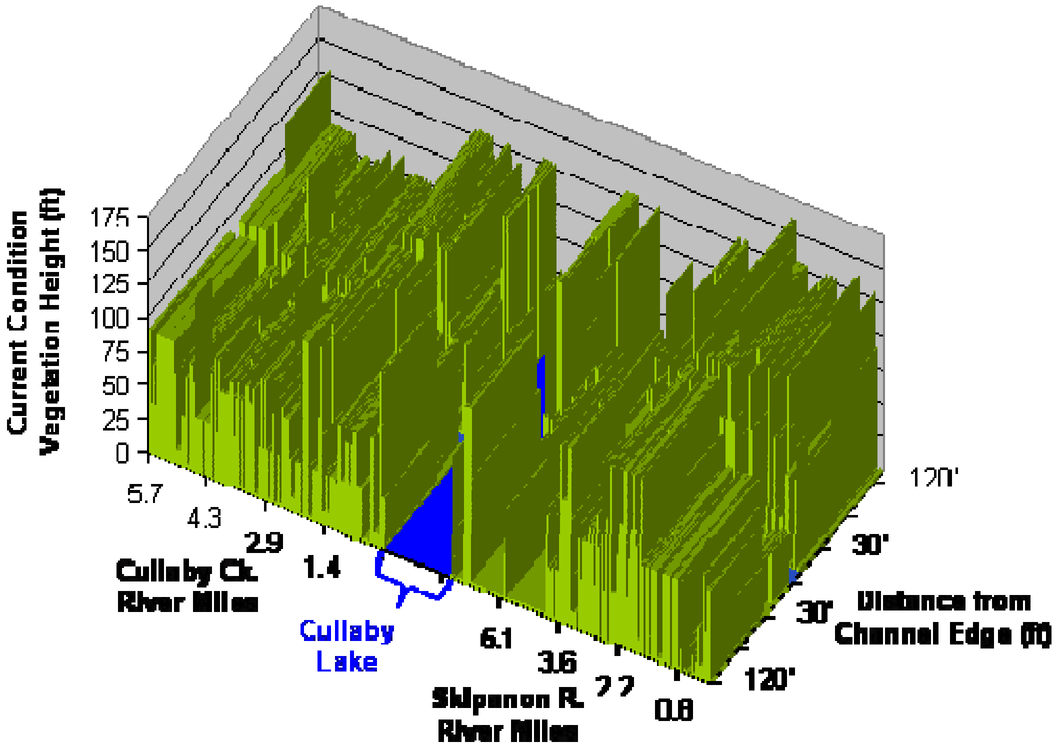


Figure 3-25. *Necanicum River Near Stream Land Cover Heights (Necanicum River Subbasin)*



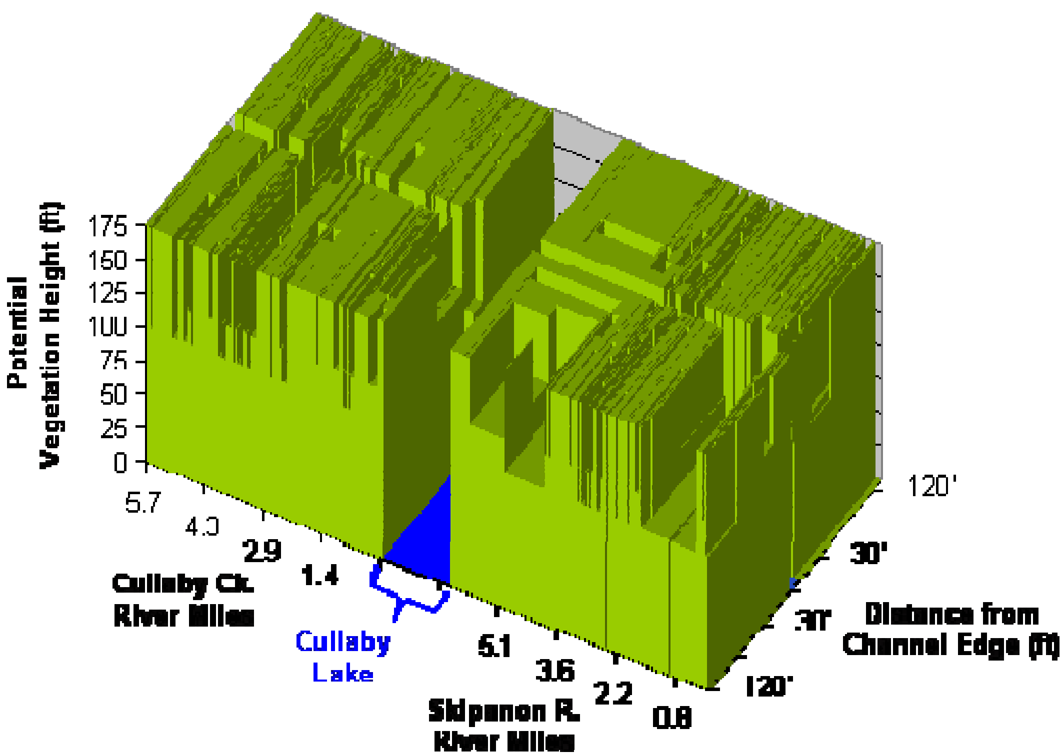


Figure 3-26. *Skipanon River and Cullaby Creek Near Stream Land Cover Heights (Lower Columbia Subbasin)*

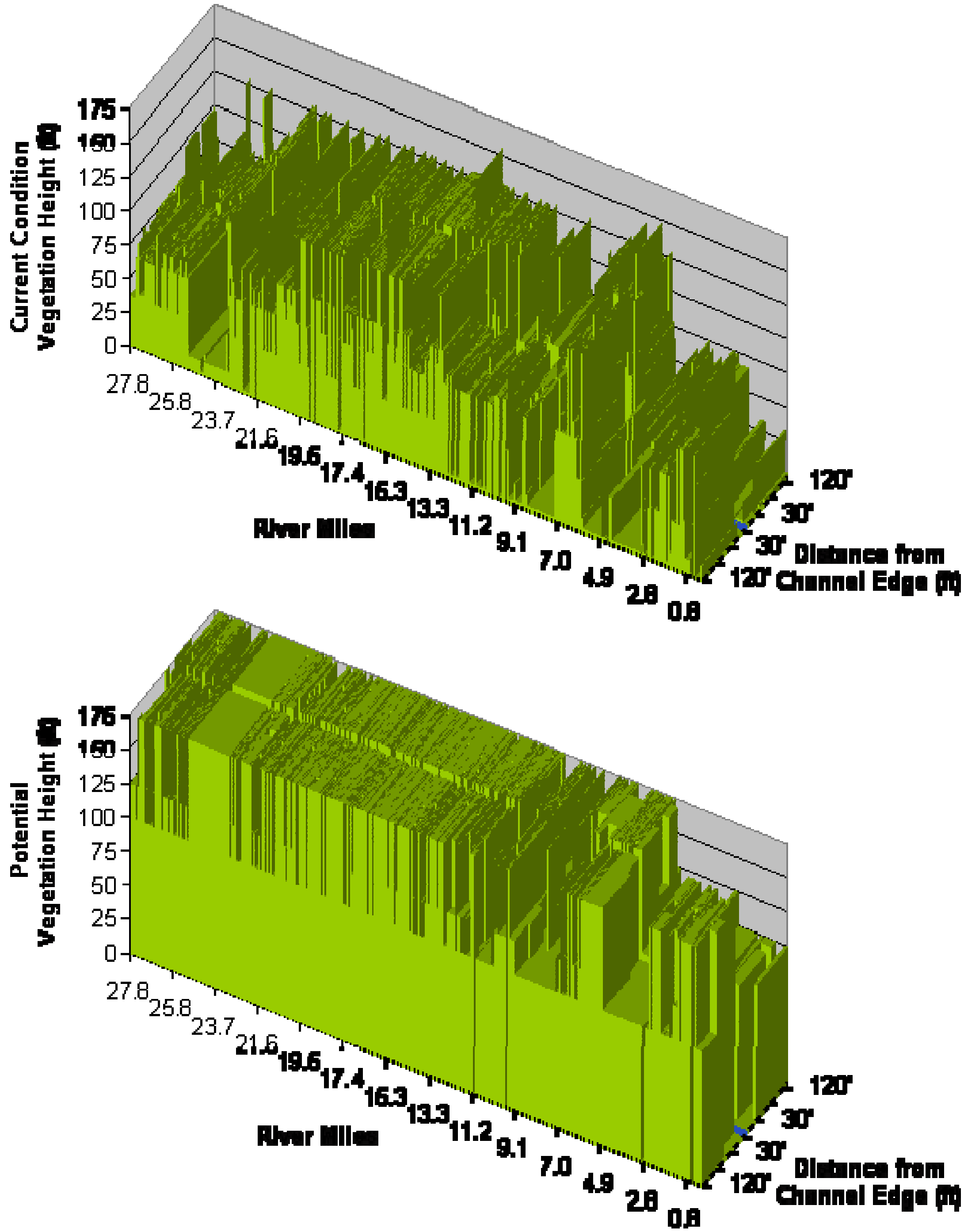


Figure 3-27. *Lewis and Clark River Near Stream Land Cover Heights (Lower Columbia Subbasin)*

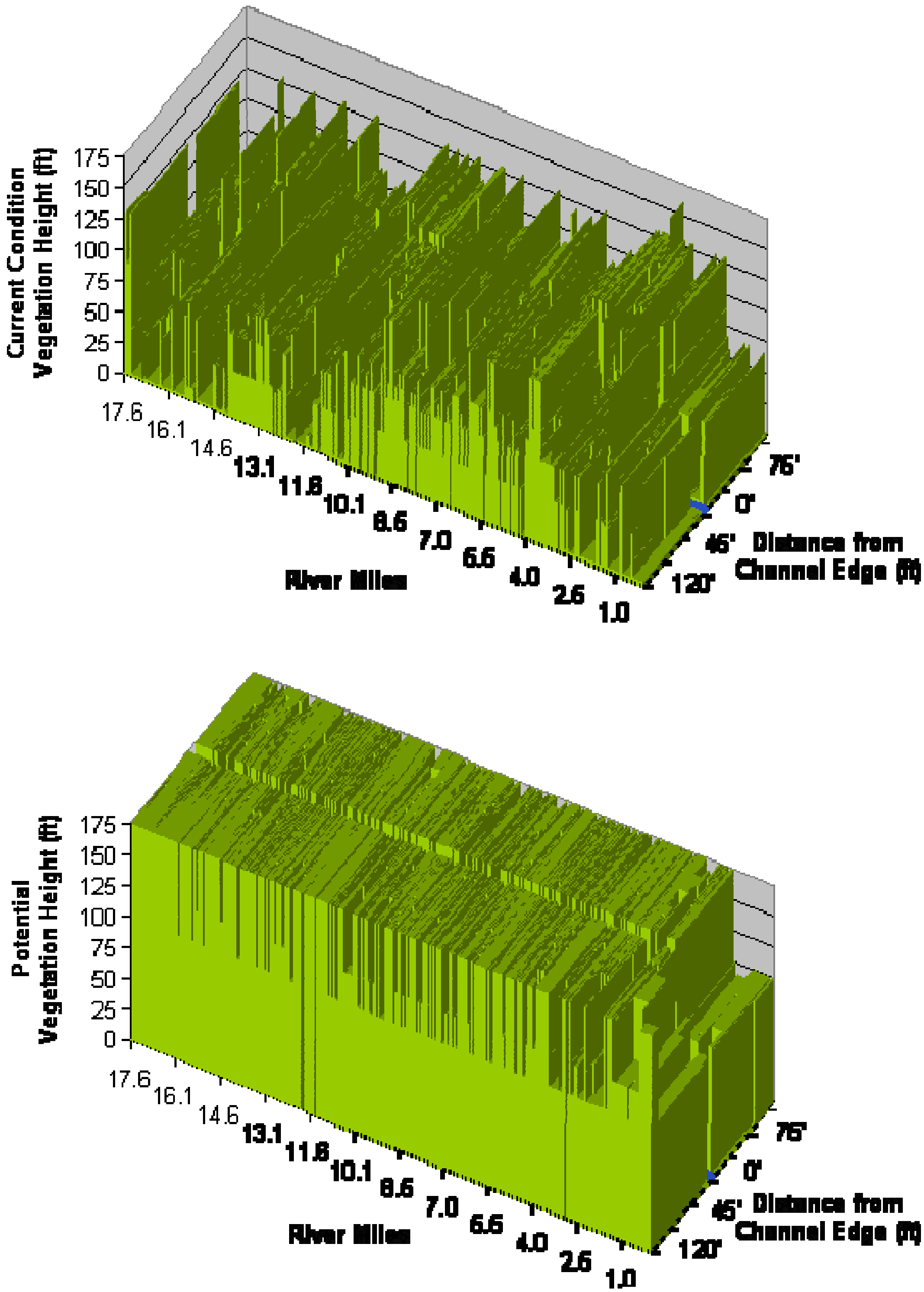


Figure 3-28. *Youngs River Near Stream Land Cover Heights (Lower Columbia Subbasin)*

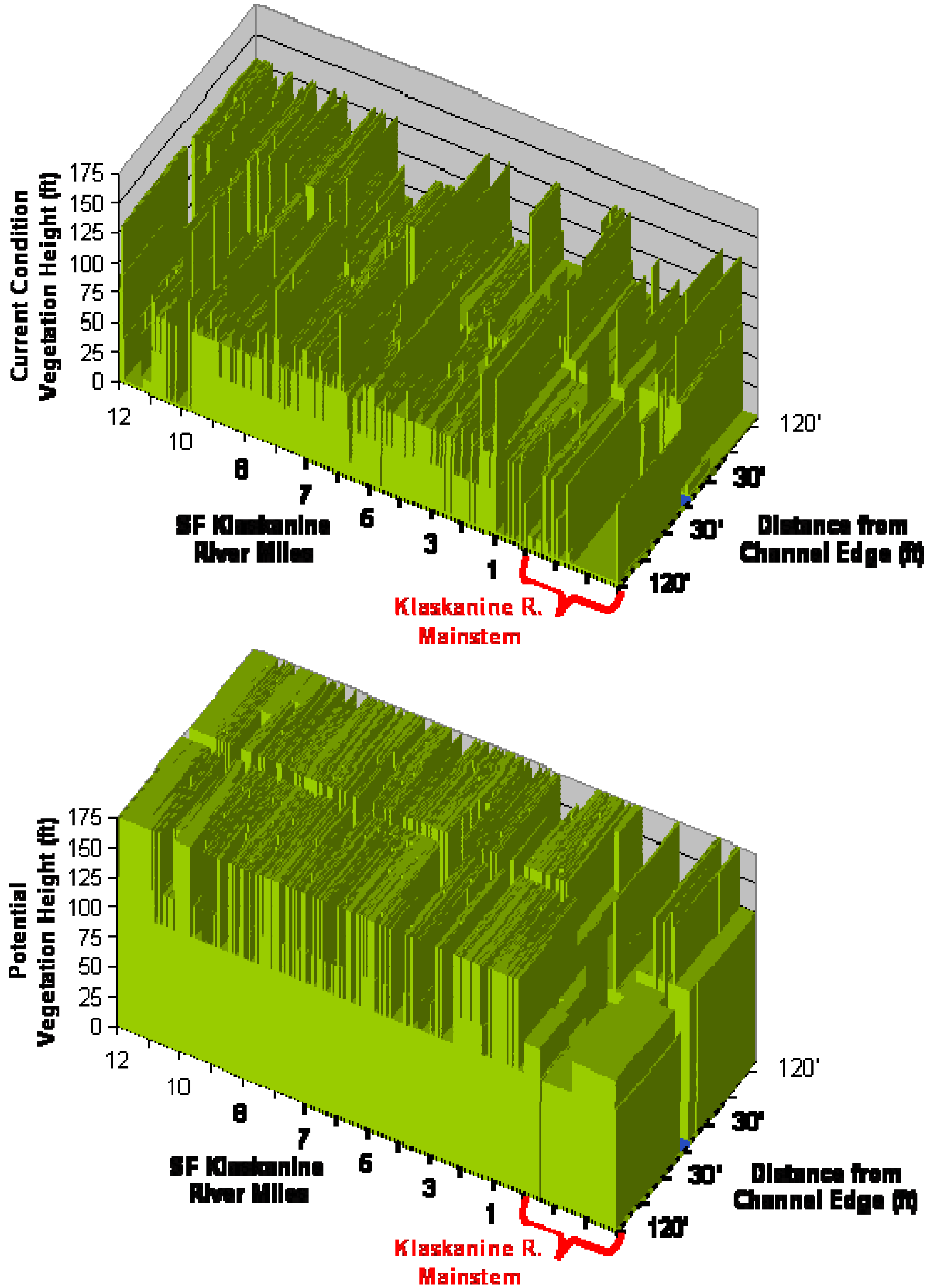


Figure 3-29. *Klaskanine River and South Fork Klaskanine River Near Stream Land cover Heights (Lower Columbia Subbasin)*

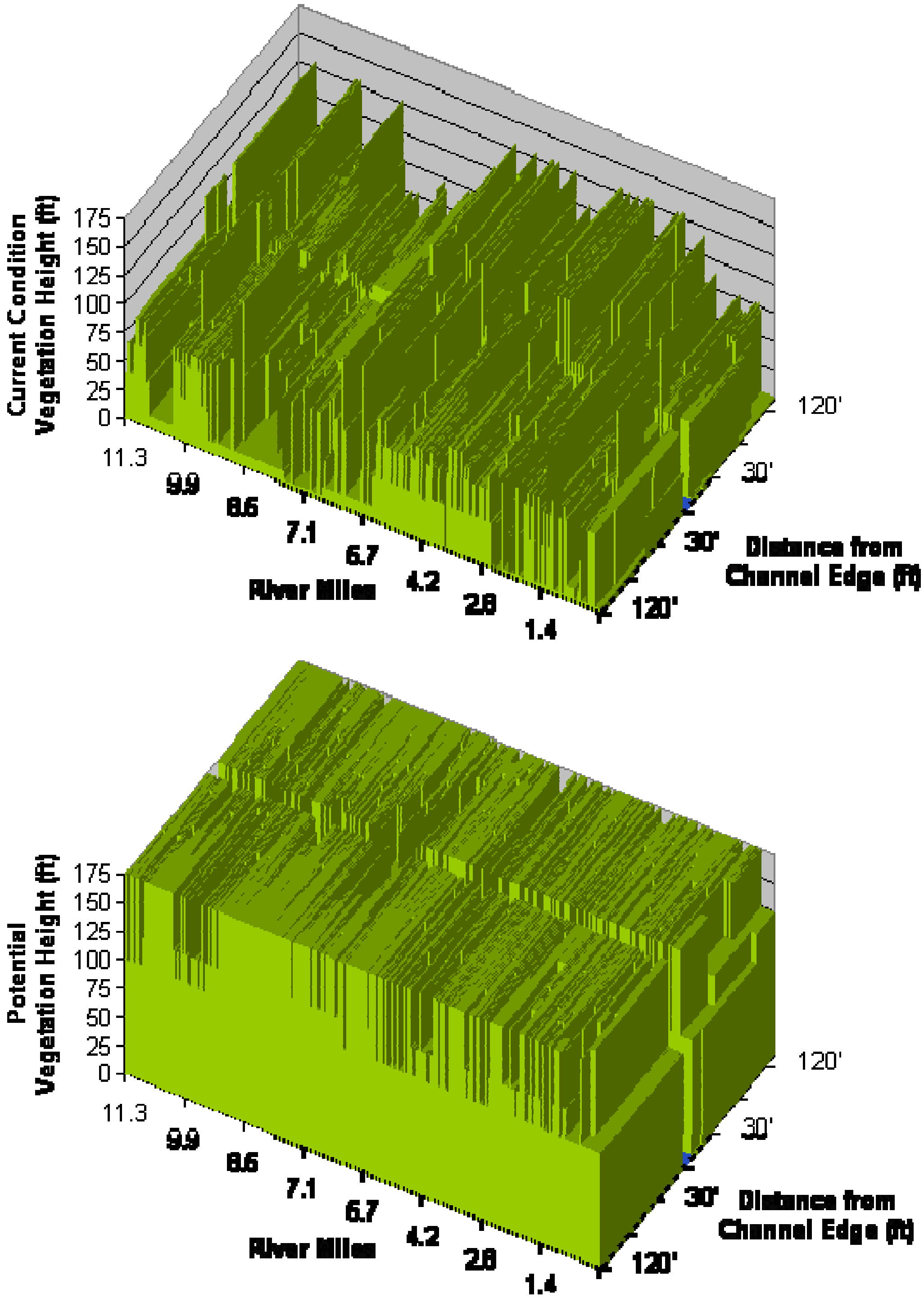


Figure 3-30. *North Fork Klaskanine River Near Stream Land Cover Heights (Lower Columbia Subbasin)*

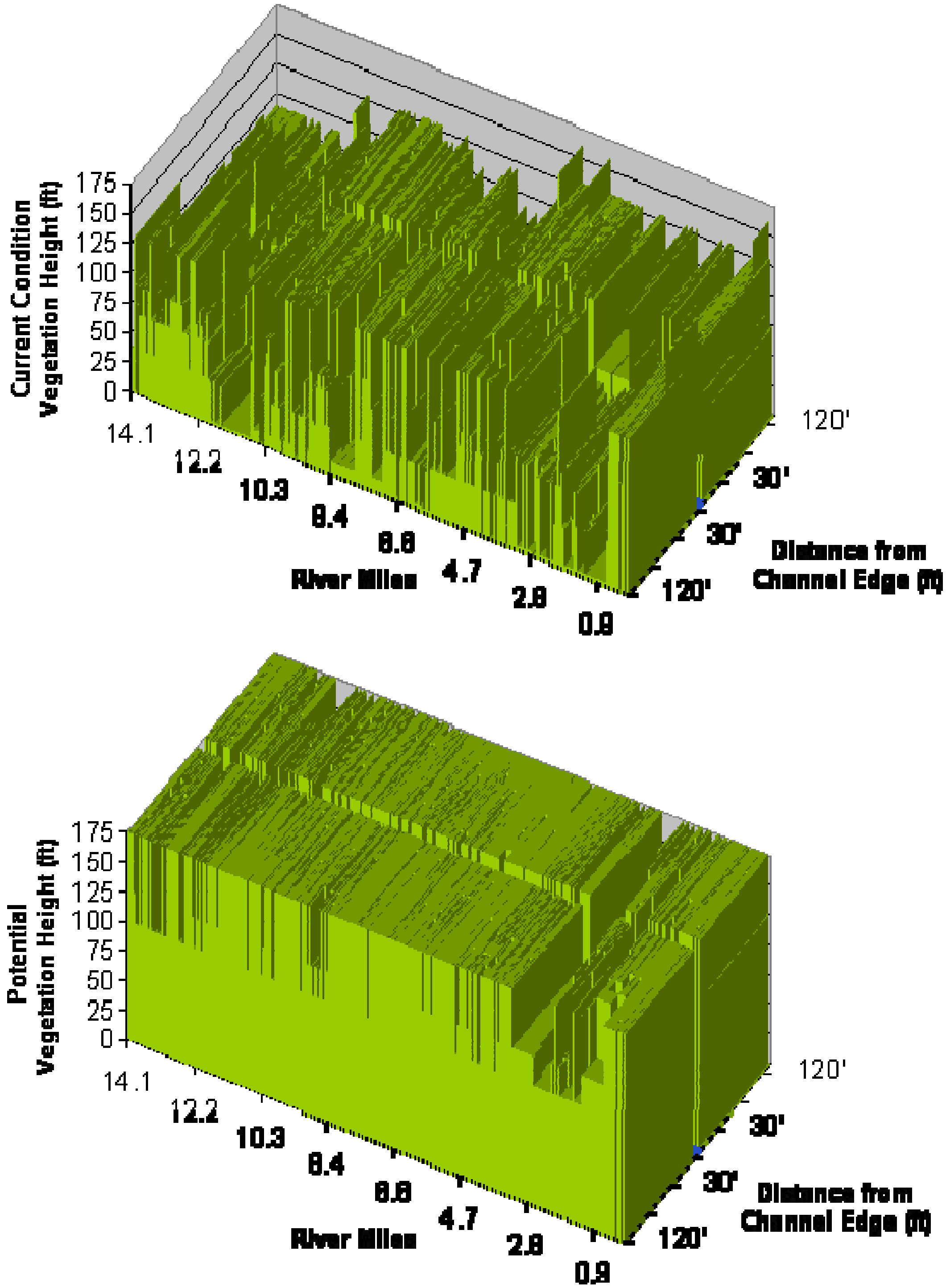


Figure 3-31. *Big Creek Near Stream Land Cover Heights (Lower Columbia Subbasin)*

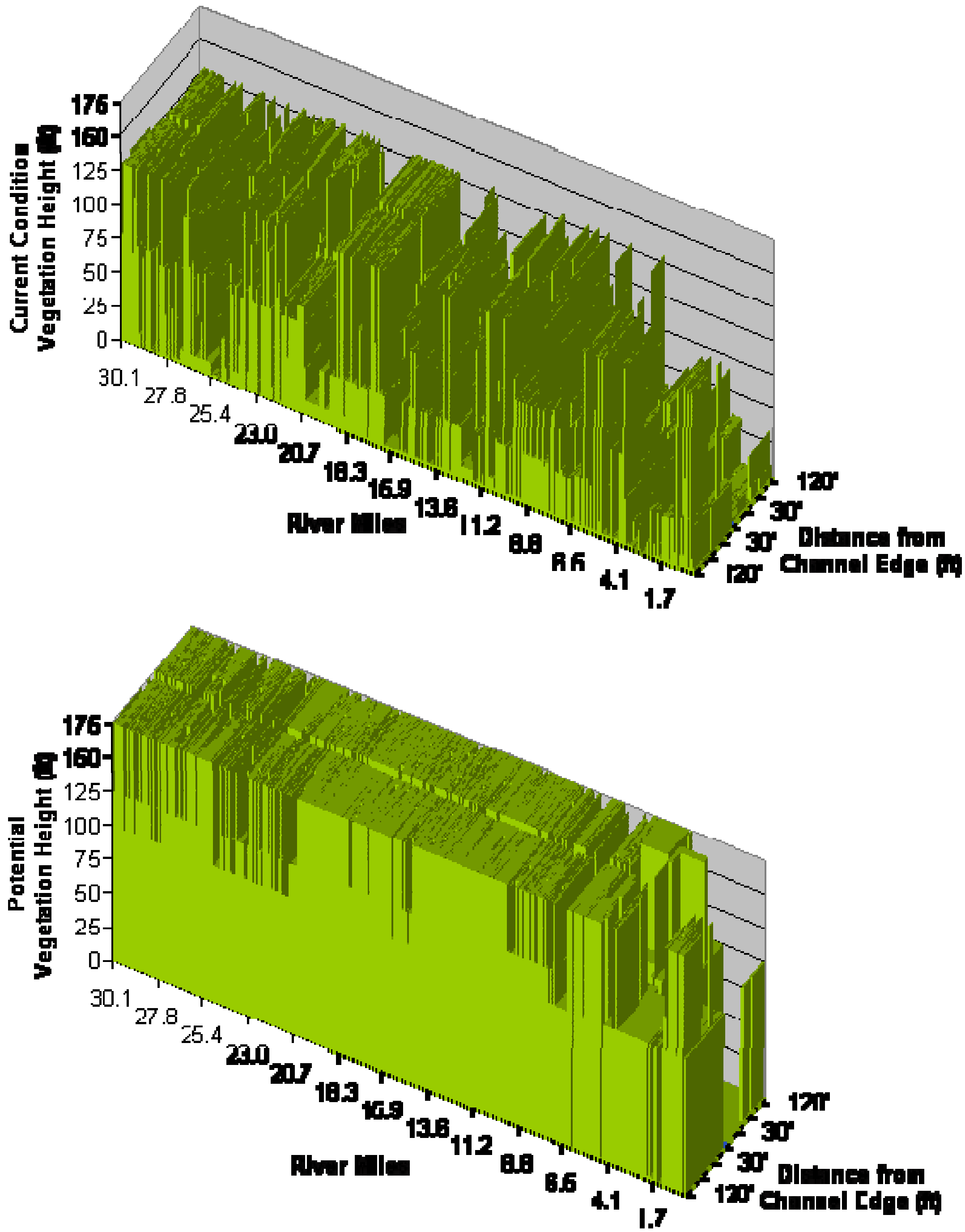
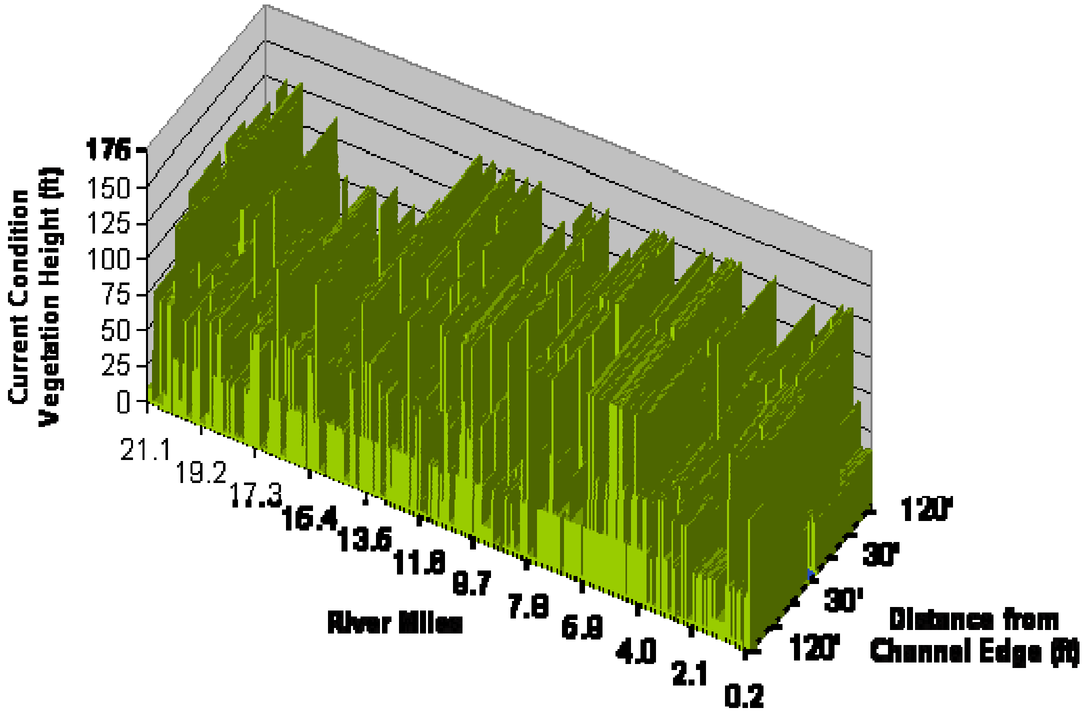


Figure 3-32. *Clatskanie River Near Stream Land Cover Heights (Clatskanie River Subbasin)*



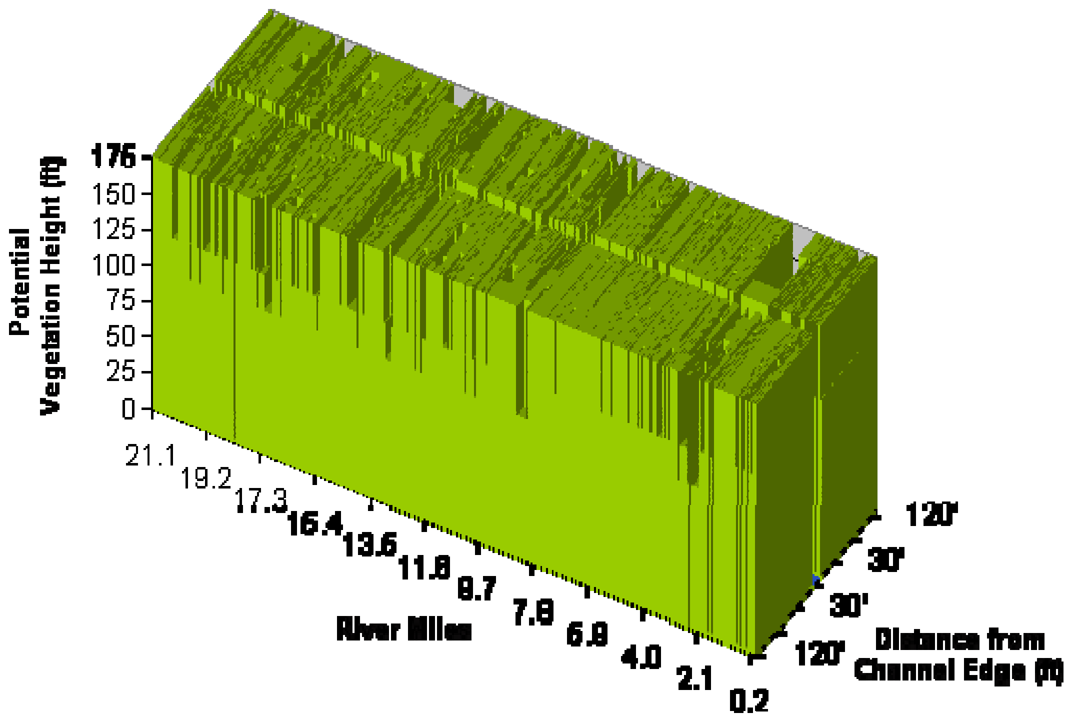
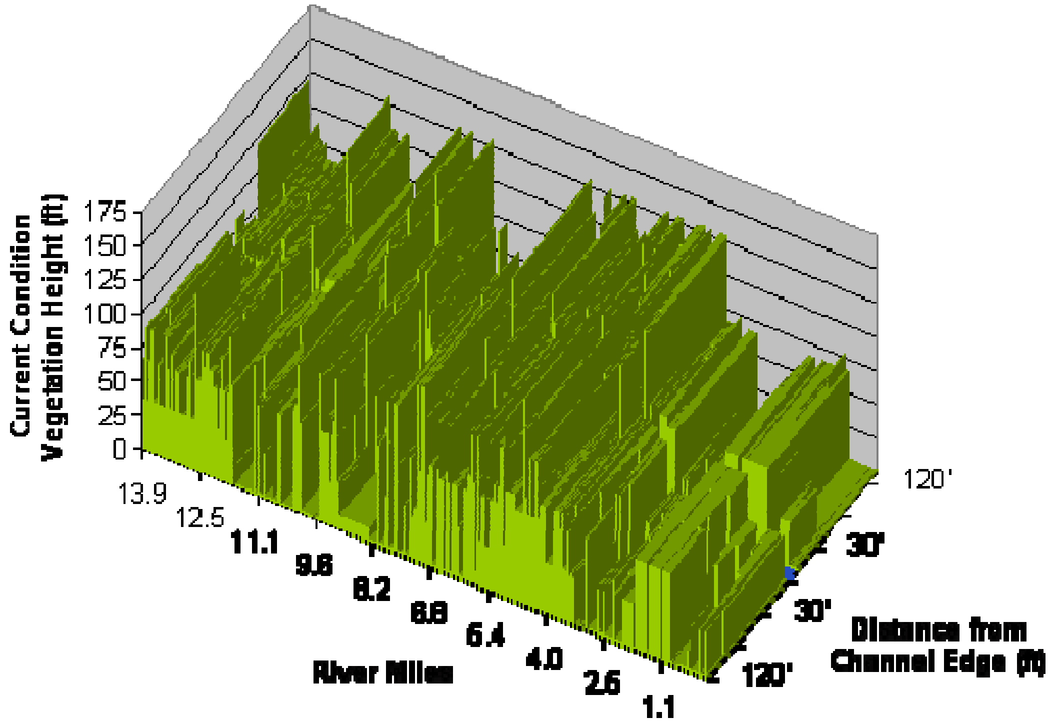


Figure 3-33. *Beaver Creek Near Stream Land Cover Heights (Clatskanie River Subbasin)*



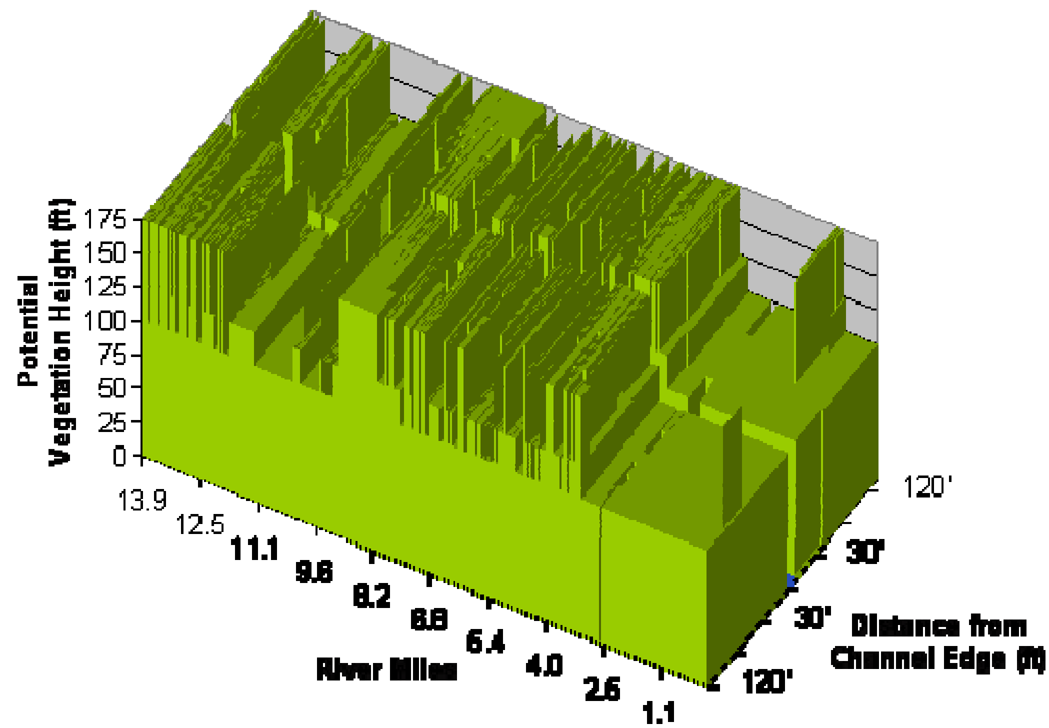


Figure 3-34. *Tide Creek Near Stream Land Cover Heights (Clatskanie River Subbasin)*

3.6 HYDROLOGY

3.6.1 Methodology Used for Mass Balance Development

FLIR sampled stream temperature data can be used to develop a mass balance for stream flow using minimal ground level data collection points. Simply identifying mass transfer areas is an important step in quantifying heat transfer within a stream network. For example, using FLIR temperature data, Oregon DEQ identified mass transfer areas occurring in the Nehalem River subbasin streams. Several of the subsurface mass transfer areas were unmapped and the relative thermal and hydrologic impact to the stream system was not previously quantified.

All stream temperature changes that result from mass transfer processes (i.e., tributary confluence, point source discharge, groundwater inflow, etc.) can be described mathematically using the following relationship:

$$T_{mix} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{mix})} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{up} + Q_{in})}$$

where,

Q_{up}: Stream flow rate upstream from mass transfer process
Q_{in}: Inflow volume or flow rate
Q_{mix}: Resulting volume or flow rate from mass transfer process ($Q_{up} + Q_{in}$)
T_{up}: Stream temperature directly upstream from mass transfer process
T_{in}: Temperature of inflow
T_{mix}: Resulting stream temperature from mass transfer process assuming complete mix

All water temperatures (i.e., T_{up}, T_{in} and T_{mix}) are apparent in the FLIR sampled stream temperature data. Provided that at least one instream flow rate is known the other flow rates can be calculated.

Water volume losses are often visible in FLIR imagery since diversions and water withdrawals usually contrast with the surrounding thermal signature of landscape features. Highly managed stream flow regimes can become complicated where multiple diversions and return flows mix or where flow diversions and returns are unmapped and undocumented. In such cases it becomes important to establish the direction of flow (i.e., influent or effluent). With the precision afforded by FLIR sampled stream temperatures, effluent flows can be determined when temperatures are the same. Temperature differences indicate that the flow is influent. This holds true even when observed temperature differences are very small. The rate of water loss from diversions or withdrawals cannot be easily calculated. Oregon DEQ estimates water withdrawal flow rates from the water right information maintained by Oregon Water Resources Department (OWRD).

In this fashion, a mass balance can be developed from relatively few instream measurements, FLIR stream temperature data and water rights data. **Potential flow rates** are easily calculated by removing all water withdrawals and agriculture return flows.

Discussion of Assumptions and Limitations for Mass Balance Methodology

1. **Small mass transfer processes are not accounted**. A limitation of the methodology is that only mass transfer processes with measured ground level flow rates or those that cause a quantifiable change in stream temperature with the receiving waters (i.e., identified by FLIR data) can be analyzed and included in the mass balance. For example, a tributary with an unknown flow rate that cause small temperature changes (i.e., less than $\pm 0.5^{o}F$) to the receiving stream cannot be accurately included. *This assumption can lead to an under estimate of influent mass transfer processes.*

2. **Limited ground level flow data limit the accuracy of derived mass balances**. Errors in the calculations of mass transfer can become cumulative and propagate in the methodology since validation can only be performed at sites with known flow rates. *These mass balance profiles should be considered estimates of a steady state flow condition*.

3. **Water withdrawals are not directly quantified**. Instead, water right data is obtained from the POD and WRIS OWRD databases. An assumption is made that these water rights are being used if water availability permits. *This assumption can lead to an over estimate of water withdrawals.*

4. **Water withdrawals are assumed to occur only at OWRD mapped points of diversion sites.** There may have been additional diversions occurring throughout the stream network. *This assumption can lead to an underestimate of water withdrawals and an under estimate of potential flow rates.*

5. **It is not possible to determine the amount of return flows derived from ground water withdrawals relative to those derived from instream withdrawals.** Some of the irrigated water comes from ground water sources. Therefore, one should assume that portions of the return flows are derived from ground water sources. Return flows can occur over long distances from irrigation application and generally occur at focal points down gradient from multiple irrigation applications. It is not possible to estimate the portion of irrigation return flow that was pumped from ground water rights. In the potential flow condition all return flows are removed from the mass balances. *This assumption can lead to an under estimate of potential flow rates.*

6. **Return flows may deliver water that is diverted from another watershed.** In some cases, irrigation canals transport diverted water to application areas in another drainage. This is especially common in low gradient meadows, cultivated fields and drained wetlands used for agriculture production. The result is that accounting for a tributary flow in the potential flow condition is extremely difficult. DEQ is unable to track return flows to withdrawal origins between drainage areas. *When return flows are removed in the potential flow condition this assumption can lead to an under estimate of potential tributary flow rates.*

Table 3-9. Mass transfer processes and cumulative flow rates by drainage area.

	Number of Mass Transfer Processes					Mass Transfer Process Flow Rates (cfs)					
	Tributary Inflows	Return Flows	Subsurface Inflows	Water Withdrawals	Total	Upstream Boundary Condition3	Tributary Inflows4	Return Flows	Subsurface Inflows5	Water Withdrawals6	Total Flow per Drainage7
Nehalem R.	36	0	2	37	75	3	247	0	3	-8	245
Rock Creek	8	0	5	6	19	2	15	0	6	-4	19
Salmonberry R.	8	0	8	0	16	2	26	0	11	0	39
Cook Creek	4	0	6	0	10	4	12	0	8	0	24
NF Nehalem R.	18	1	2	6	27	1	54	12	3	-13	57
Totals	74	1	23	49	147	12	354	12	31	-25	

[3] The upstream boundary condition is the upper most extent for which the mass balance was completed (Nehalem River - RM 111.1, Rock Creek - RM 25.9, Salmonberry River - RM 16.0, Cook Creek - RM 6.7, and North Fork Nehalem River - RM 20.2).
[4] Tributary flows are identified and quantified using FLIR data and derived mass balance flows.
[5] Subsurface flows are identified and quantified using FLIR data and derived mass balance flows.
[6] Water withdrawals are calculated from OWRD databases for points of diversion and the water rights information system. Data base queries and linking are performed by DEQ staff.
[7] The total flow per drainage represents the flow at the mouth of each stream system.

3.6.2 Results - Mass Balances

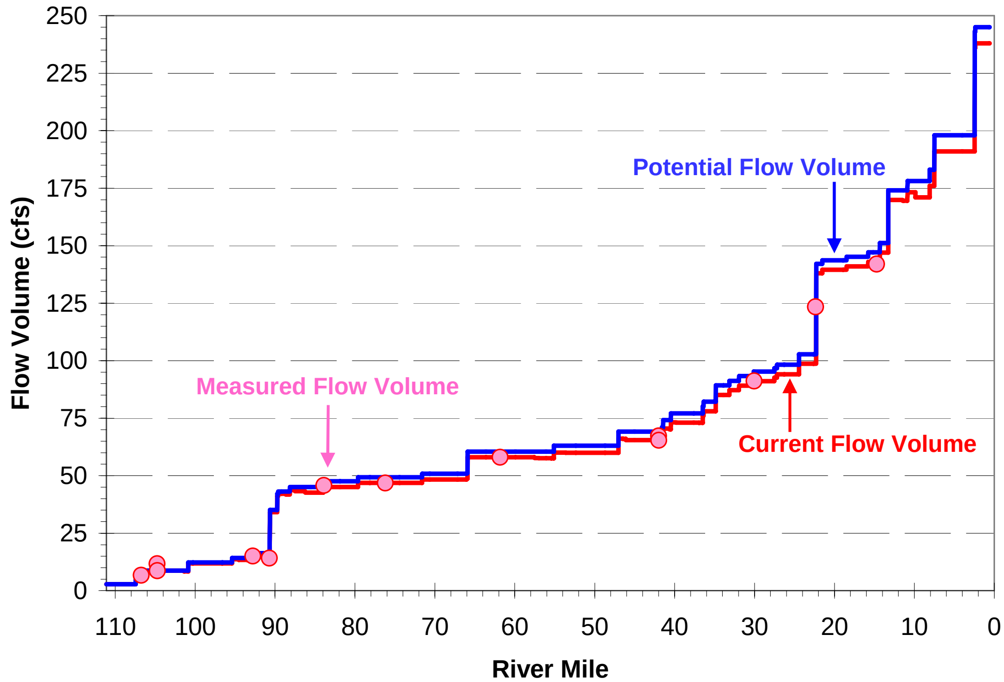


Figure 3-35. *Mass balance developed for the Nehalem River using instream gage data, instream measured data, FLIR temperature data, and water rights data.*

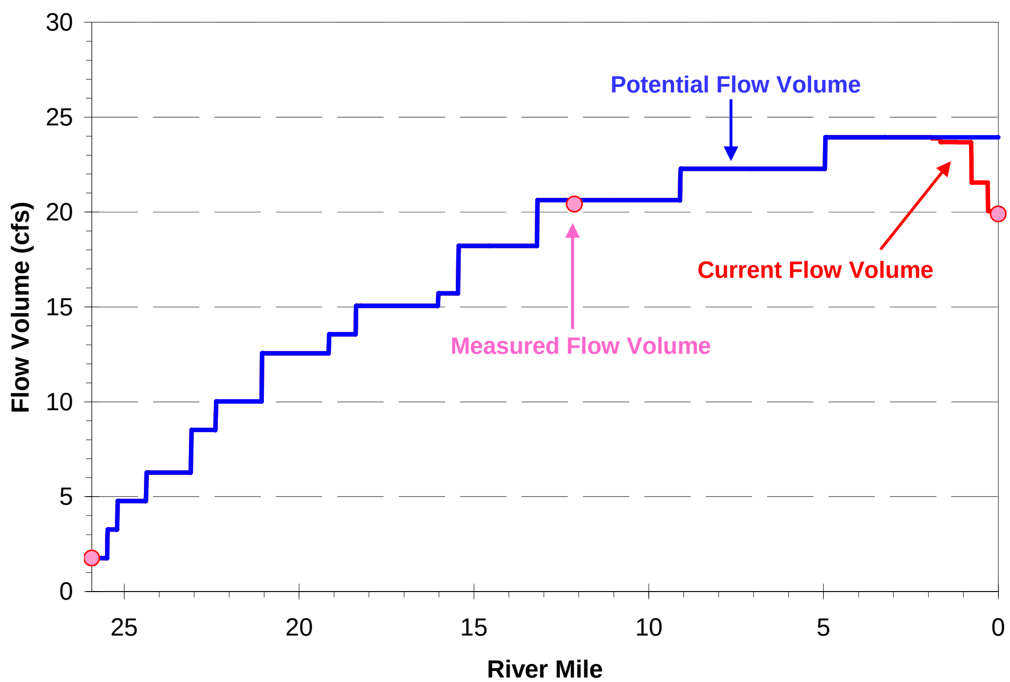


Figure 3-36. *Mass balance developed for Rock Creek using instream measured data, FLIR temperature data and water rights data.*

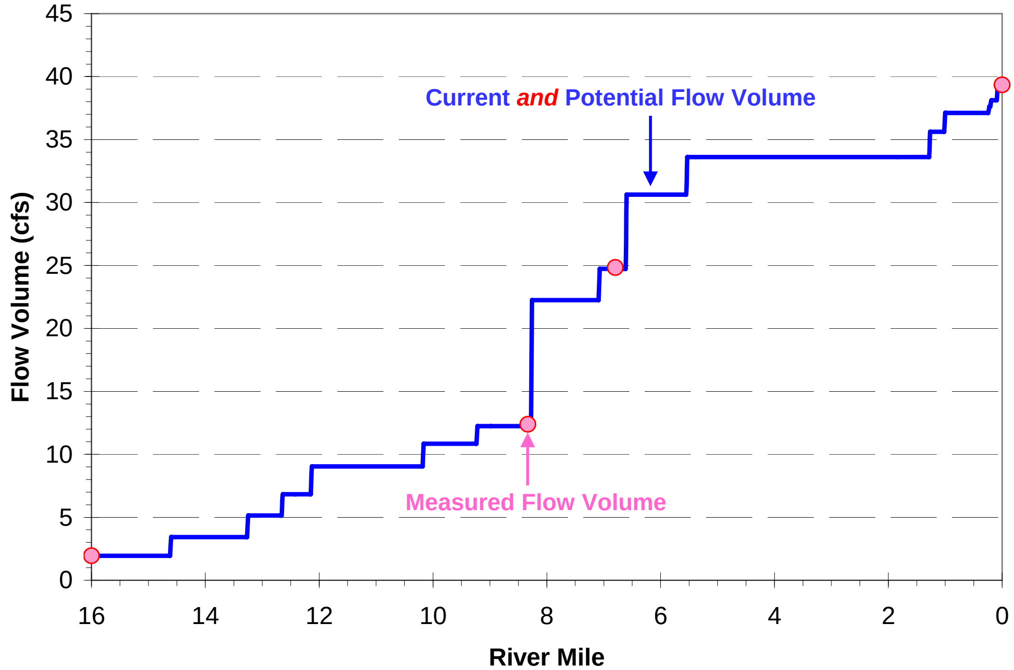


Figure 3-37. *Mass balance developed for the Salmonberry River using instream measured data, FLIR temperature data and water rights data (this stream has no official Points of Diversion).*

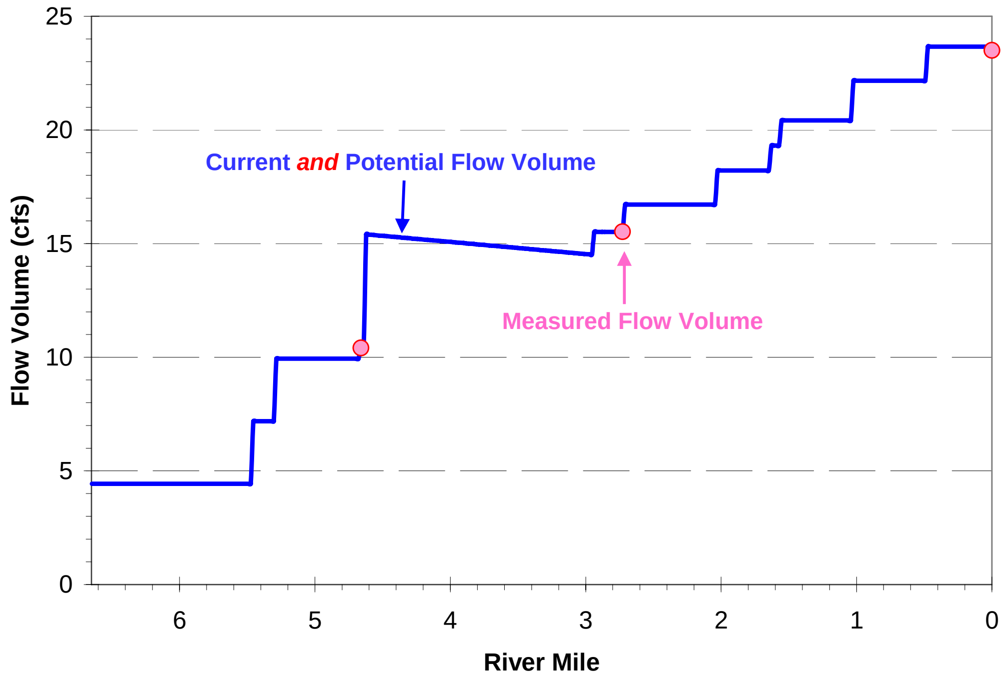


Figure 3-38. *Mass balance developed for Cook Creek using instream measured data, FLIR temperature data and water rights data (this stream has no official Points of Diversion).*

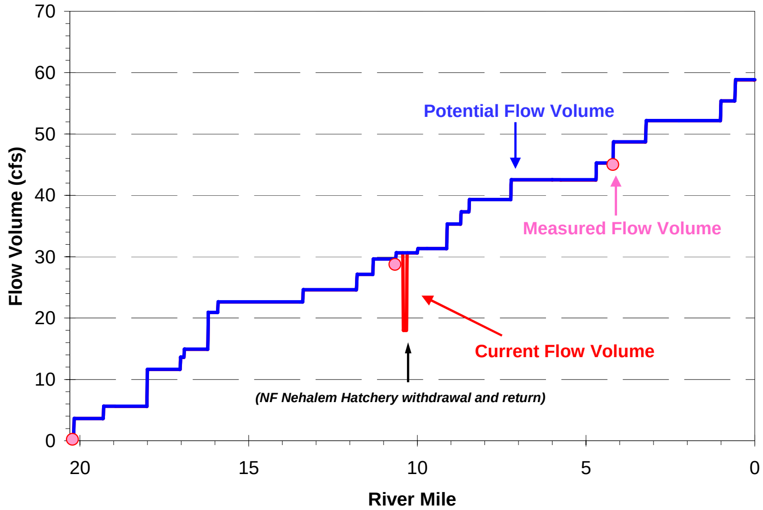


Figure 3-39. *Mass balance developed for the North Fork Nehalem River using instream measured data, FLIR temperature data and water rights data.*

3.7 Topographic Shade Angle

The maximum **topographic shade angle** is calculated to the east, south and west, relative to the stream segment node. In each direction (east, south and west) TTools steps away from the stream sampling every other pixel for elevation and calculating topographic shade angle. TTools records the value (in degrees) and the X and Y coordinates of the point that represents maximum topographic shade angle.

$$\textbf{Topographic Angle} = \tan^{-1}\left(\frac{\textbf{Elevation Above Stream}}{\textbf{Distance from Stream}}\right)$$

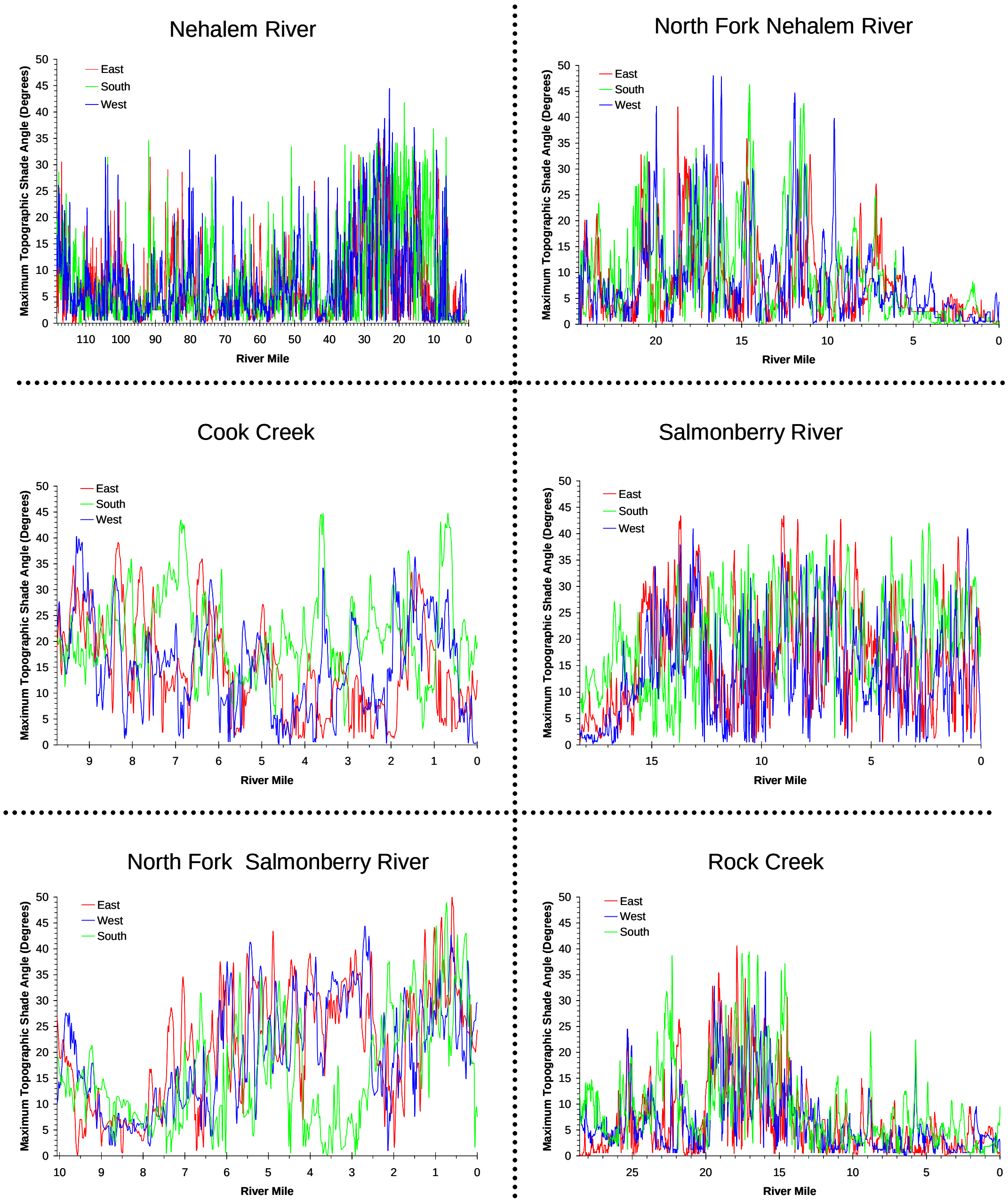


Figure 3-40. *Maximum topographic shade angles sampled from digital elevation models.*