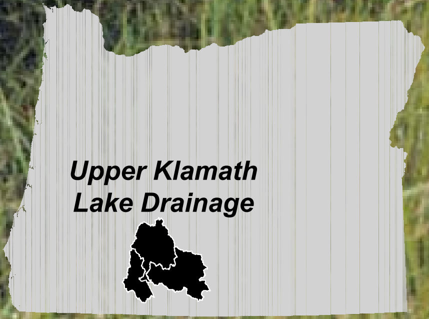
Upper Klamath Lake Drainage Channel Morphology Assessment

Methodology

State of Oregon Department of Environmental Quality



North Fork Sprague River

Channel Morphology Assessment Methodology

Step 1. **Stream channel edges are digitized from rectified digital aerial photography at 1:5,000 or less**. These channel boundaries establish the near stream disturbance zone, 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. **Assess the accuracy of sampled near stream disturbance zone width in estimating ground level bankfull width measurements**. Establish statistical limitations for near stream disturbance zone width values when used for estimating bankfull width.

Step 4. **Relate bankfull discharge to drainage area**. Bakke et al. (2000) presents regional curves developed for Klamath Basin and surrounding area stream systems that relate bankfull discharge to drainage area. Two relationships are developed based on drainage area magnitude: less than 100 mi^2 and greater than 100 mi^2.

Step 5. **Relate bankfull cross-sectional area to bankfull discharge.** Bakke et al. (2000) also presents a regional curve relationship for bankfull channel cross-sectional area and drainage area that is valid for drainage areas less than 100 mi^2 (260 km^2). While this relationship proves useful is assessing small order streams, it becomes limited since it applies to those with small drainage areas. In attempt to extend the relationship between bankfull channel cross-sectional area and drainage area, DEQ has developed a relationship between bankfull channel cross-sectional area and bankfull discharge. This relationship is based on the Bakke et al. (2000) relationship for bankfull discharge and drainage area less than 100 mi^2 (260 km^2).

Channel Morphology Assessment Methodology (continued)

Step 6. **Relate bankfull cross-sectional area to drainage area.** Substituting the Bakke et al. (2000) regional curve relationships for bankfull discharge into the DEQ derived relationship for bankfull cross-sectional area and bankfull discharge allows bankfull cross-sectional area to be expressed as a function for all drainage areas. The two bankfull discharge regional curve relationships presented by Bakke et al. (2000) produce two relationships for bankfull cross-sectional area: less than (100 mi^2) 260 km^2 and greater than (193 mi^2) 500 km^2. The area between the two curves is simply the highest value of the less than 260 km^2 relationship extended to the greater than 500 km^2 relationship. Since the two relationships predict different values for the 260 km^2 to 500 km^2 region of the curve, the higher values are used.

Step 7. **Methodology Overview**

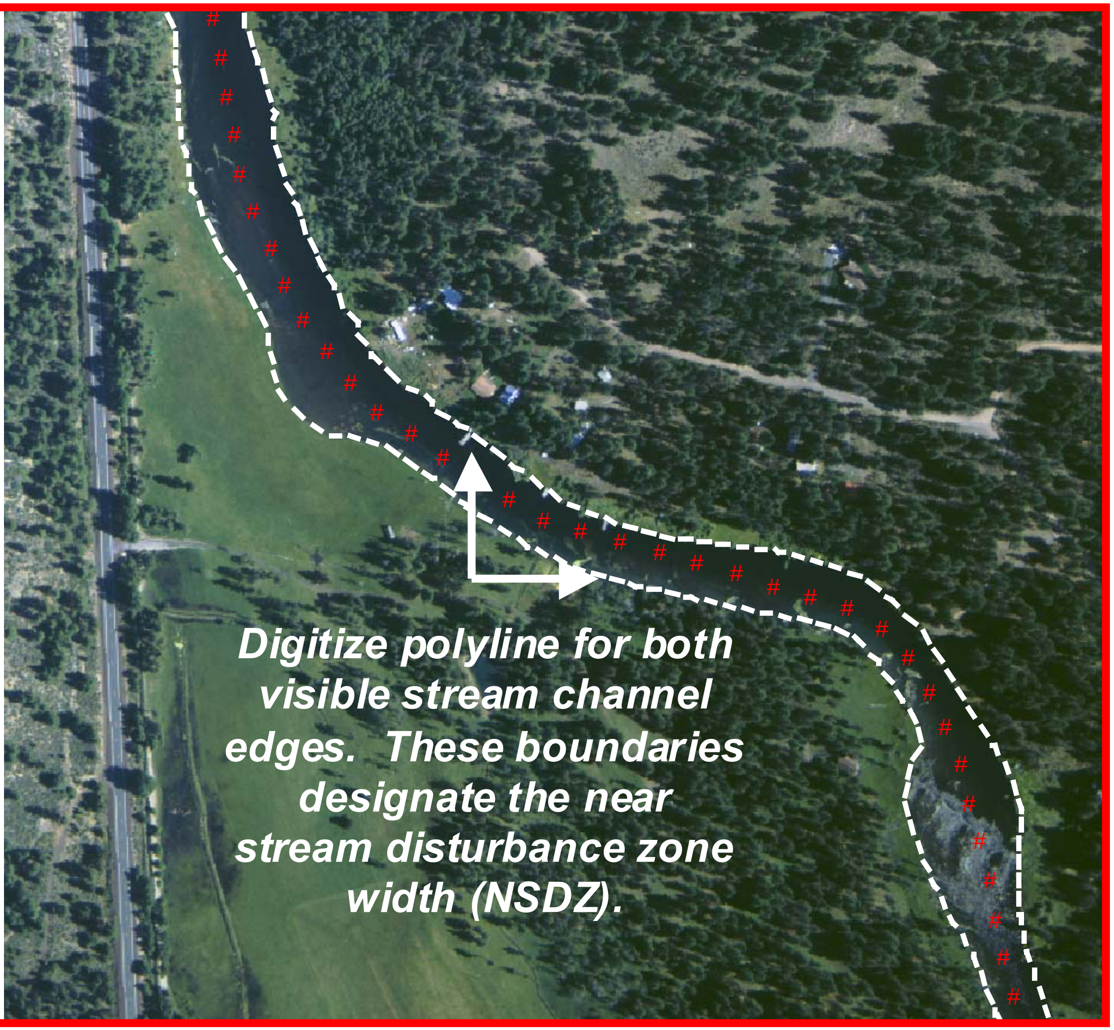
Step 8. **Validate Methodology** - It should be noted that validation of the DEQ derived curve for drainage areas greater than 500 km^2 is not possible due to lack of data. There is an implicit assumption that the relationship between bankfull discharge and bankfull cross-sectional area is valid throughout the range of drainage areas analyzed by this approach (0 to 10,000 km^2).

Step 9. **Relate Bankfull Width Values to Stream Type, Width to Depth and Drainage Area.** Bankfull width can be estimated as a function of width to depth ratio and cross-sectional area. Using this relationship for bankfull width, it is possible to relate bankfull width to drainage area and width to depth ratios. This relationship is used for a best fit to measured NSDZ width data. Drainage areas for all stream data nodes are calculated from 30-meter digital elevation model data. Width to depth ratios are the variable used as the basis for the best fit relationship. All derived width to depth ratios are within published ranges for level I stream types (Rosgen, 1996).

Step 10. **Potential bankfull width is developed as a function of stream type, drainage area and width to depth ratios**. Using the regional curve relationships for bankfull width as a threshold condition, departures from this threshold become evident. Potential bankfull widths are assumed to be those that are at or below the regional curve threshold for the appropriate stream type.

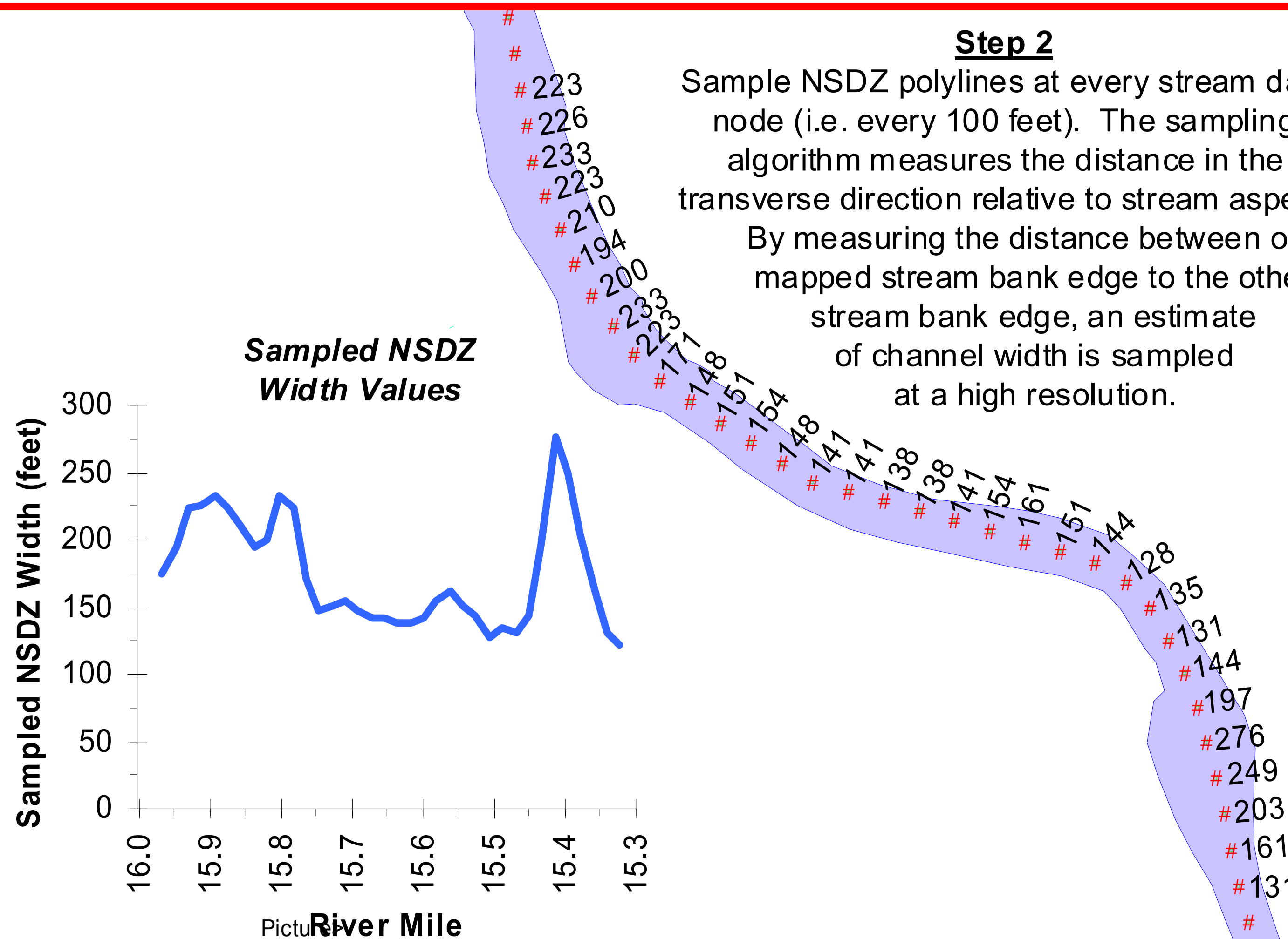
Step 1
Digitize Channel Edge Polylines at 1:5,000

ODEQ refers to these stream edge boundaries as the near stream disturbance zone width (NSDZ).



Step 2

Sample NSDZ polylines at every stream data node (i.e. every 100 feet). The sampling algorithm measures the distance in the transverse direction relative to stream aspect. By measuring the distance between one mapped stream bank edge to the other stream bank edge, an estimate of channel width is sampled at a high resolution.

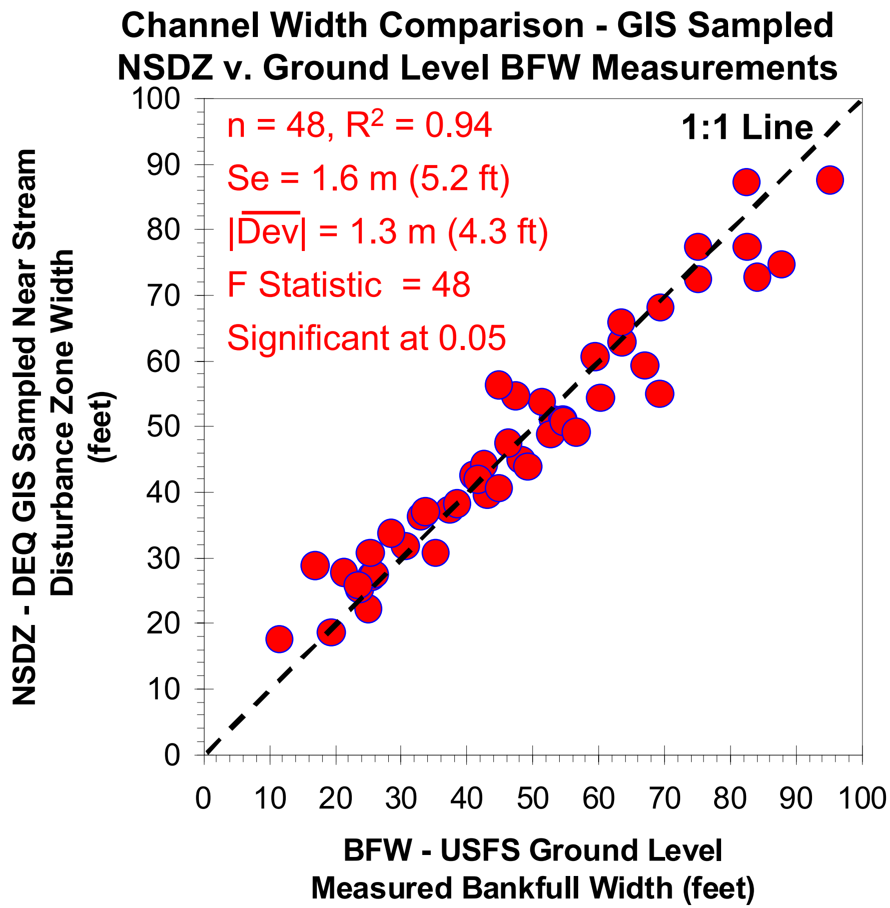


Step 3

Assess accuracy of ODEQ NSDZ width sampled data compared to USFS bankfull width ground level measurements.

In general, the NSDZ width serves as an accurate estimate of bankfull widths. When compared to ground level bank full width data, NSDZ width samples have a correlation coefficient of 0.94, a standard error or 5.2 feet and an average absolute deviation of 4.3 feet.

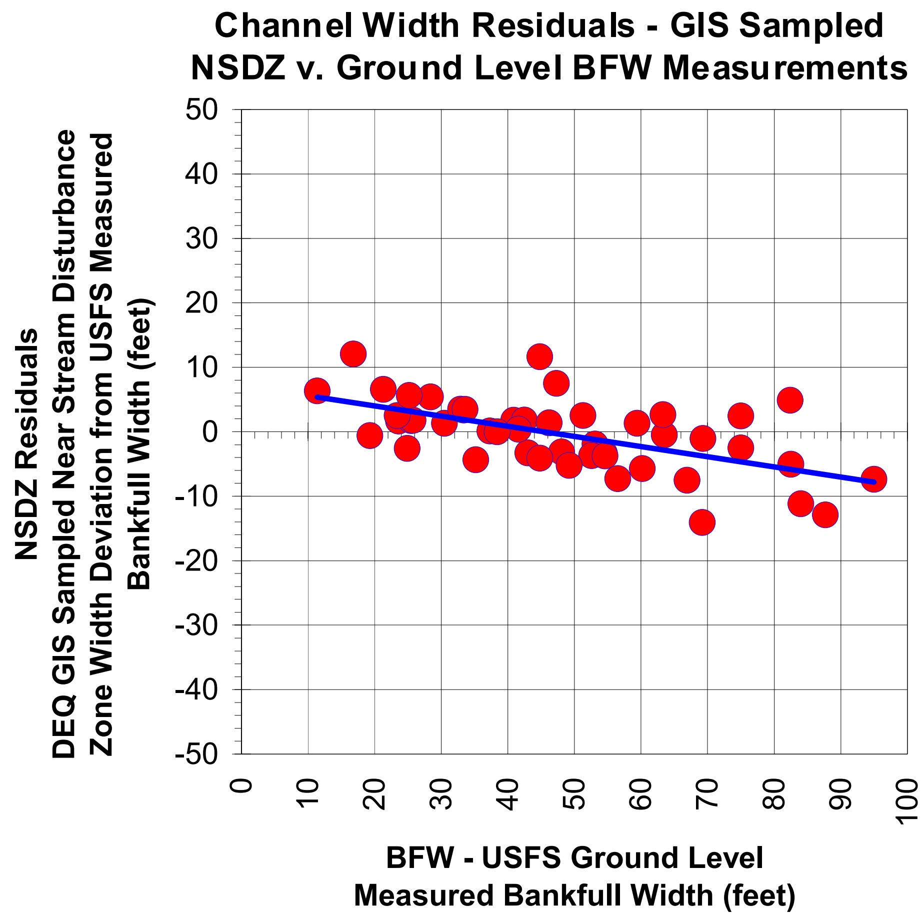
NSDZ width samples can be used to estimate bankfull width provided that statistical accuracy limitations are acknowledged.



Step 3 (continued)

Assess accuracy of ODEQ NSDZ width sampled data compared to USFS bankfull width ground level measurements.

This methodology may over estimate bankfull widths for narrow stream channels and under estimate bankfull channel width for wider stream channels. Sources of error include limited by aerial photo resolution, plan view line of sight to the stream channel boundaries and the clarity of the channel edge (i.e. there must be a visibly defined channel boundary). There is an obvious bias to the methodology towards features visible in plan view. Vertical features (i.e. channel incisions, cut banks, flood plain relief, etc.) can be difficult to distinguish for aerial photos.



Step 4

Relate bankfull discharge to drainage area

Bakke et al. (2000) presents regional curves developed for Klamath Basin and surrounding area stream systems that relate bankfull discharge to drainage area. Two relationships are developed based on drainage area magnitude: less than 100 mi^2 and greater than 100 mi^2.

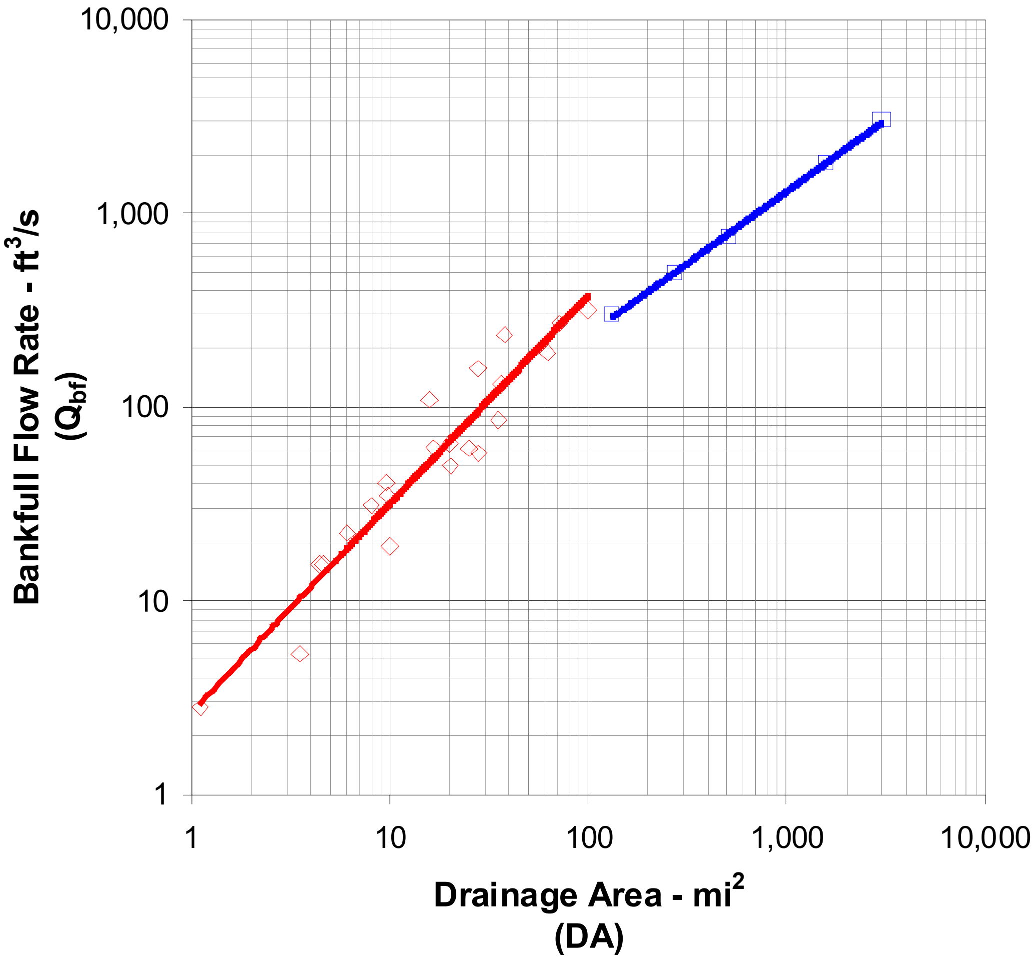
Metric Units	*English Units*
A_{bf}: Bankfull Cross-Sectional Area (m^2) DA: Drainage Area (km^2) Q_{bf}: Bankfull Discharge (m^3/s)	A_{bf}: Bankfull Cross-Sectional Area (ft^2) DA: Drainage Area (mi^2) Q_{bf}: Bankfull Discharge (ft^3/s)

Bankfull Discharge as a Function of Drainage Area, For all DA < 260 km^2 $Q_{bf} = 0.0272 \cdot DA^{1.0740}$ ($R^2 = 0.91$) For all DA > 260 km^2 $Q_{bf} = 0.1090 \cdot DA^{0.7400}$ ($R^2 > 0.99$) (Bakke et al., 2000)	Bankfull Discharge as a Function of Drainage Area, For all DA < 100 mi^2 $Q_{bf} = 2.6694 \cdot DA^{1.0740}$ ($R^2 = 0.91$) For all DA > 100 mi^2 $Q_{bf} = 7.7843 \cdot DA^{0.7400}$ ($R^2 > 0.99$) (DEQ analysis)

<u>Step 4</u> (continued)
Relate bankfull discharge to drainage area

Bankfull Discharge v. Drainage Area

Regional curves for bankfull discharge and drainage area – Klamath Basin and surround area stream systems (data from Bakke et al., 2000).



For DA < 260 km² (100 mi²)

Metric Units

$Q_{bf} = 0.0272 \cdot DA^{1.0740}$

English Units

$Q_{bf} = 2.6694 \cdot DA^{1.0740}$

n = 21, $R^2 = 0.91$

Se = 0.1600 m³/s (5.65 ft³/s)

F Statistic = 213

Significant at 0.05

For DA > 260 km² (100 mi²)

Metric Units

$Q_{bf} = 0.1090 \cdot DA^{0.7400}$

English Units

$Q_{bf} = 7.7843 \cdot DA^{0.7400}$

n = 5, $R^2 > 0.99$

Se = 0.0179 m³/s (0.63 ft³/s)

F Statistic = 2090

Significant at 0.05

Step 5

Relate bankfull cross-sectional area to bankfull discharge

Bakke et al. (2000) also presents a regional curve relationship for bankfull channel cross-sectional area and drainage area that is valid for drainage areas less than 100 mi^2 (260 km^2). While this relationship proves useful is assessing small order streams, it becomes limited since it applies to those with small drainage areas. In attempt to extend the relationship between bankfull channel cross-sectional area and drainage area, DEQ has developed a relationship between bankfull channel cross-sectional area and bankfull discharge. This relationship is based on the Bakke et al. (2000) relationship for bankfull discharge and drainage area less than 100 mi^2 (260 km^2).

Metric Units	*English Units*
A_{bf}: Bankfull Cross-Sectional Area (m^2) DA: Drainage Area (km^2) Q_{bf}: Bankfull Discharge (m^3/s)	A_{bf}: Bankfull Cross-Sectional Area (ft^2) DA: Drainage Area (mi^2) Q_{bf}: Bankfull Discharge (ft^3/s)

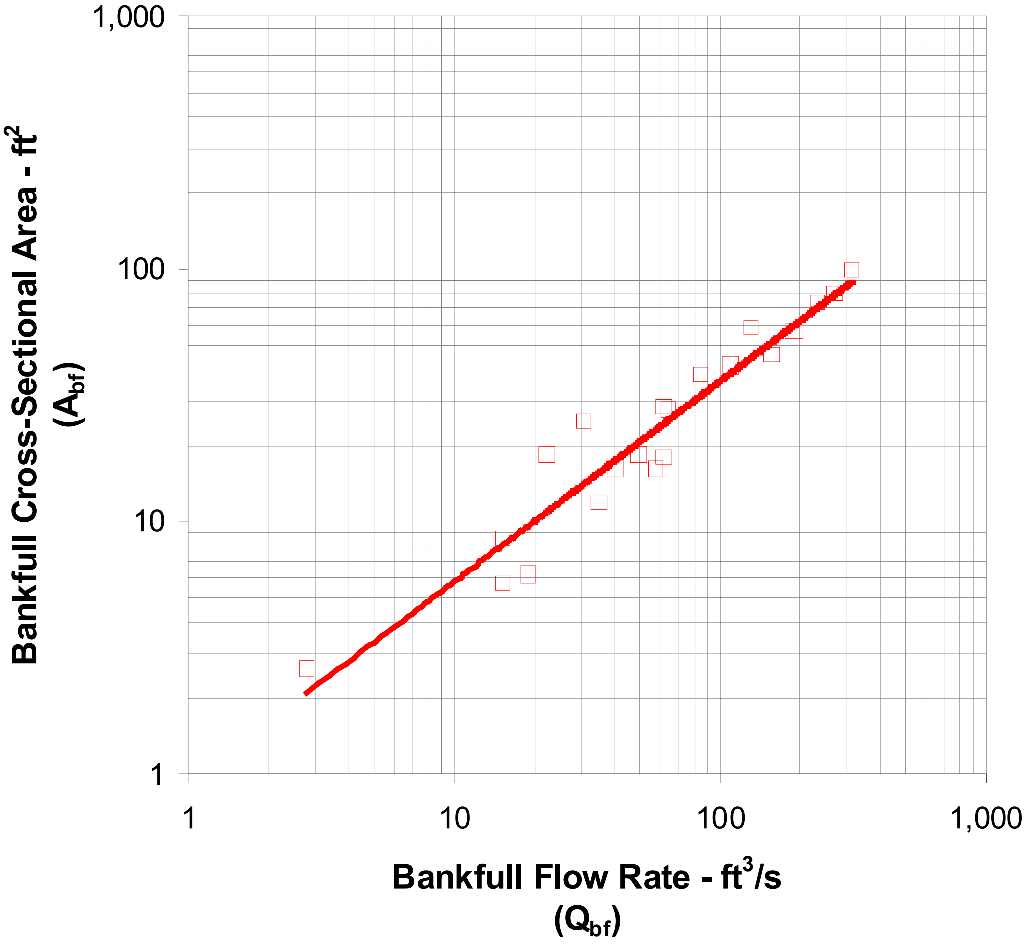
Bankfull Cross-Sectional Area as a Function of Bankfull Discharge, $A_{bf} = 1.5009 \cdot Q_{bf}^{0.7792}$ (DEQ analysis)	Bankfull Cross-Sectional Area as a Function of Bankfull Discharge, $A_{bf} = 1.0050 \cdot Q_{bf}^{0.7792}$ (DEQ analysis)

Step 5 (continued)

Relate bankfull cross-sectional area to bankfull discharge

Bankfull Cross-Sectional Area v. Bankfull Discharge

Relationship between bankfull cross-sectional area and bankfull discharge – Klamath Basin and surround area stream systems (data from Bakke et al., 2000, DEQ analysis)



For DA < 260 km² (100 mi²)

Metric Units

$A_{bf} = 1.5009 \cdot DA^{0.7792}$

English Units

$A_{bf} = 1.0050 \cdot DA^{0.7792}$

n = 21, R^2 = 0.92

Se = 0.55 m² (5.92 ft²)

F Statistic = 231

Significant at 0.05

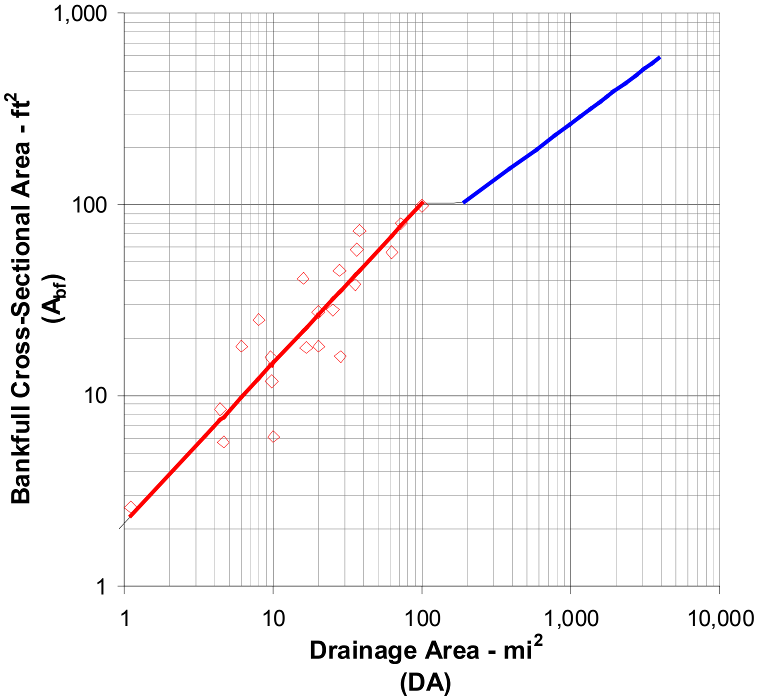
Step 6
Relate bankfull cross-sectional area to drainage area

Substituting the Bakke et al. regional curve relationships for bankfull discharge into the DEQ derived relationship for bankfull cross-sectional area and bankfull discharge allows bankfull cross-sectional area to be expressed as a function for all drainage areas.

The two bankfull discharge regional curve relationships presented by Bakke et al. are accounted for in the figure below and produce two relationships for bankfull cross-sectional area: less than (100 mi^2) 260 km^2 and greater than (193 mi^2) 500 km^2. The area between the two curves is simply the highest value of the less than 260 km^2 relationship extended to the greater than 500 km^2 relationship. Since the two relationships predict different values for the 260 km^2 to 500 km^2 region of the curve, the higher values are used.

Bankfull Cross-Sectional Area v. Drainage Area

Regional curve for bankfull cross-sectional area and drainage area – Klamath Basin and surround area stream systems (data from Bakke et al., 2000, DEQ analysis)



For DA < 260 km^2 (100 mi^2)

Metric Units

$A_{bf} = 0.0905 \cdot DA^{0.8369}$

English Units

$A_{bf} = 2.1603 \cdot DA^{0.8369}$

n = 21, $R^2 = 0.80$

Se = 0.19 m^2 (2.05 ft^2)

F Statistic = 80

Significant at 0.05

For DA 260 km^2 (100 mi^2) to 500 km^2 (193 mi^2)

A_{bf} = 9.5 m^2 (102.3 ft^2)

For DA > 500 km^2 (193 mi^2)

Metric Units

$A_{bf} = 0.2669 \cdot DA^{0.5766}$

English Units

$A_{bf} = 4.9731 \cdot DA^{0.5766}$

Step 7
Methodology Overview

Metric Units	*English Units*
A_{bf}: Bankfull Cross-Sectional Area (m^2) DA: Drainage Area (km^2) Q_{bf}: Bankfull Discharge (m^3/s)	A_{bf}: Bankfull Cross-Sectional Area (ft^2) DA: Drainage Area (mi^2) Q_{bf}: Bankfull Discharge (ft^3/s)
Step 4 Bankfull Discharge as a Function of Drainage Area, For all DA < 260 km^2 $Q_{bf} = 0.0272 \cdot DA^{1.0740}$ ($R^2 = 0.91$) For all DA > 260 km^2 $Q_{bf} = 0.1090 \cdot DA^{0.7400}$ ($R^2 > 0.99$) (Bakke et al., 2000)	**Step 4** Bankfull Discharge as a Function of Drainage Area, For all DA < 100 mi^2 $Q_{bf} = 2.6694 \cdot DA^{1.0740}$ ($R^2 = 0.91$) For all DA > 100 mi^2 $Q_{bf} = 7.7843 \cdot DA^{0.7400}$ ($R^2 > 0.99$) (DEQ analysis)
Step 5 Bankfull Cross-Sectional Area as a Function of Bankfull Discharge, $A_{bf} = 1.5009 \cdot Q_{bf}^{0.7792}$ (DEQ analysis)	**Step 5** Bankfull Cross-Sectional Area as a Function of Bankfull Discharge, $A_{bf} = 1.0050 \cdot Q_{bf}^{0.7792}$ (DEQ analysis)
Step 6 Bankfull Cross-Sectional Area as a Function of Drainage Area, For all DA < 260 km^2 $A_{bf} = 1.5009 \cdot (0.0272 \cdot DA^{1.0740})^{0.7792}$ *Which simplifies to,* $A_{bf} = 0.0905 \cdot DA^{0.8369}$ ($R^2 = 0.92$) DA < 260 km^2 to 500 km^2 Regression Equations Predict Differing Values. Use higher range of values. $A_{bf} = 9.5\ m^2$ DA < 500 km^2 $A_{bf} = 1.5009 \cdot (0.1090 \cdot DA^{0.740})^{0.7792}$ *Which simplifies to,* $A_{bf} = 0.2669 \cdot DA^{0.5766}$ (DEQ analysis)	**Step 6** Bankfull Cross-Sectional Area as a Function of Drainage Area, For all DA < 100 mi^2 $A_{bf} = 2.1603 \cdot DA^{0.8369}$ ($R^2 = 0.92$) DA < 100 mi^2 to 193 mi^2 Regression Equations Predict Differing Values. Use higher range of values. $A_{bf} = 102.3\ ft^2$ DA < 193 mi^2 $A_{bf} = 4.9731 \cdot DA^{0.5766}$ (DEQ analysis)

Step 8

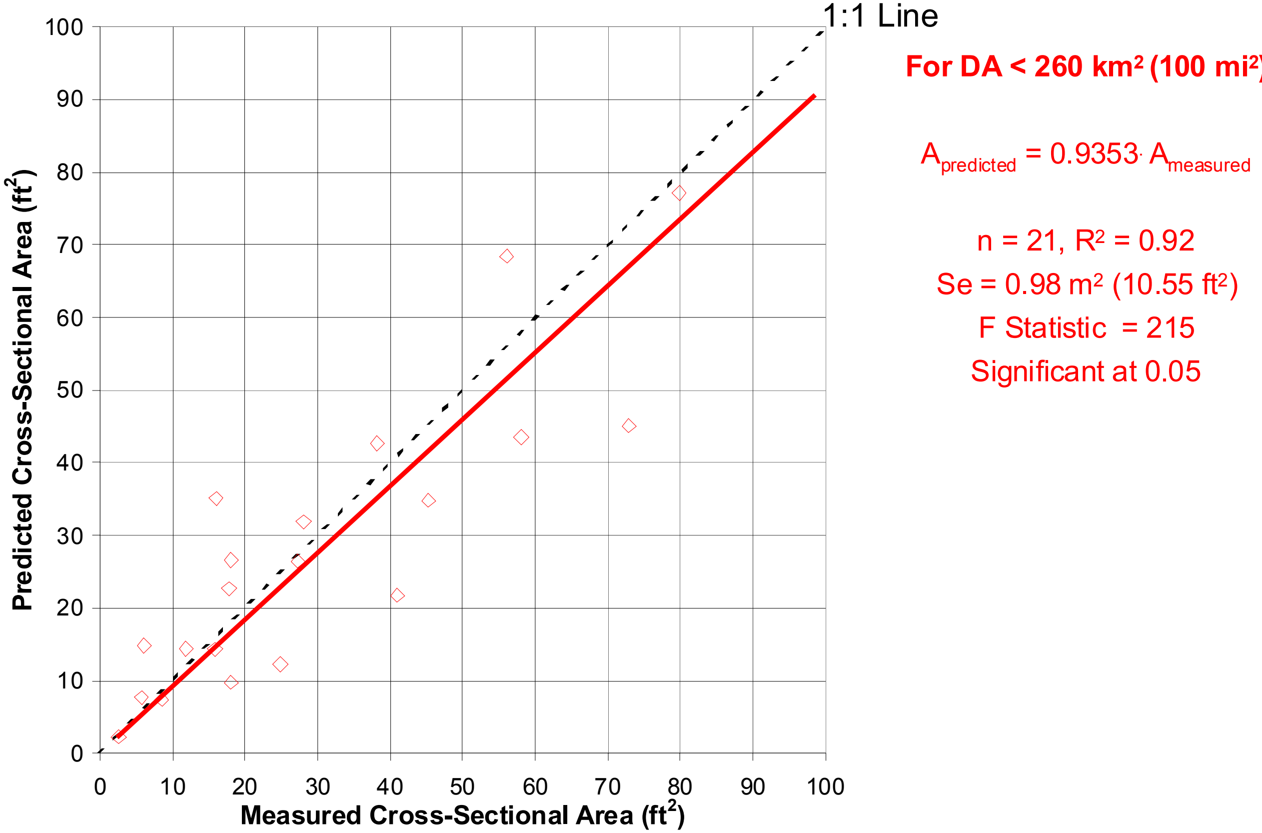
Validate Methodology

The accuracy of predicting the bankfull cross-sectional area as a function of drainage area is presented in the figure below. It should be noted that validation of the DEQ derived curve for drainage areas greater than 500 km^2 is not possible due to lack of data. There is an implicit assumption that the relationship between bankfull discharge and bankfull cross-sectional area is valid throughout the range of drainage areas analyzed by this approach (0 to 10,000 km^2).

Cross-Sectional Area Validation

Predicted v. Measured

Channel cross-sectional area - Measured vs. precited – Klamath Basin and surrounding area stream systems (data from Bakke et al., 2000, DEQ analysis).



Step 9

Relate Bankfull Width Values to Stream Type, Width to Depth and Drainage Area

Bankfull width can be estimated as a function of width to depth ratio and cross-sectional area.

$$BFW = \sqrt{W : D \cdot A_{bf}}$$

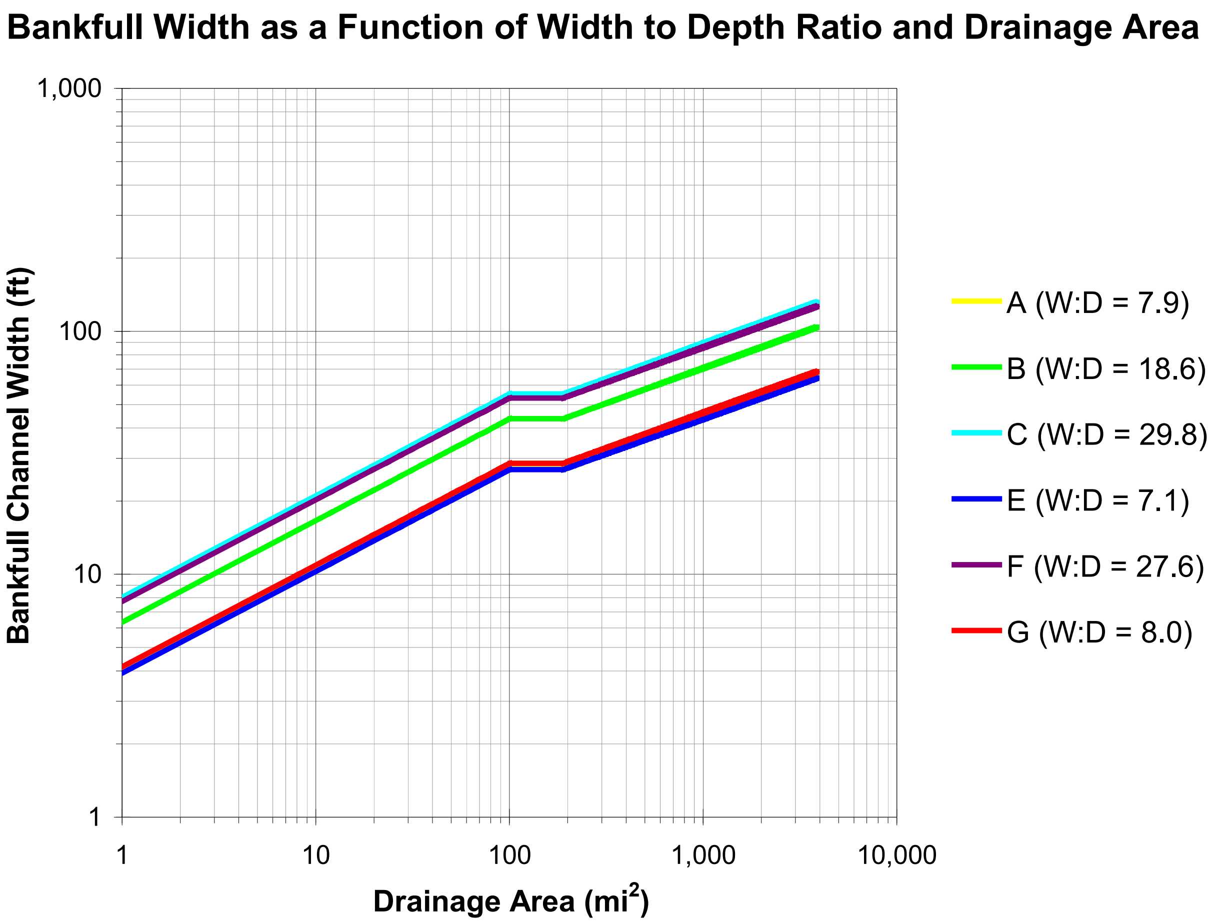
(Rosgen, 1996)

Using this relationship for bankfull width, it is possible to relate bankfull width to drainage area and width to depth ratios. This relationship is used for a best fit to measured NSDZ width data. Drainage areas for all stream data nodes are calculated from 30-meter digital elevation model data. Width to depth ratios are the variable used as the basis for the best fit relationship. All derived width to depth ratios are within published ranges for level I stream types (Rosgen, 1996).

Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
G	8.0

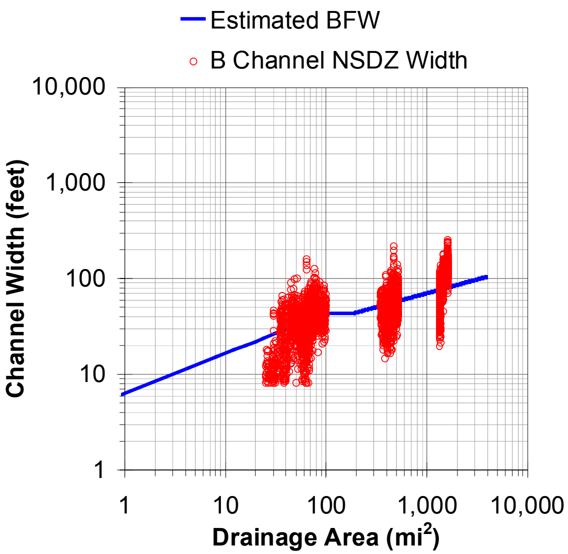
<u>Step 9</u> (continued)

Relate Bankfull Width Values to Stream Type, Width to Depth and Drainage Area



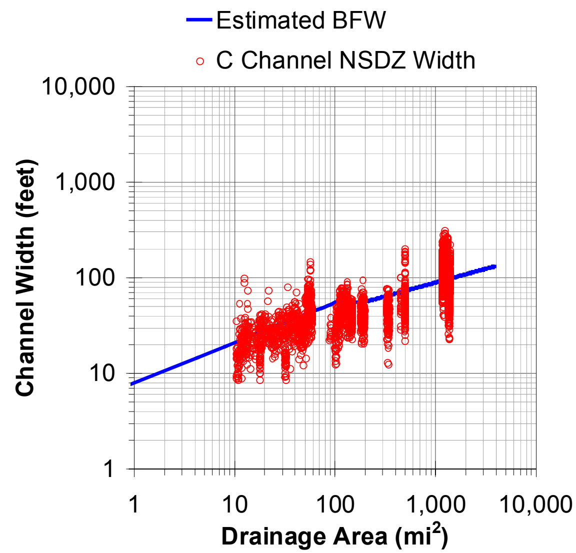
Step 9 (continued)

Relate Bankfull Width Values to Stream Type, Width to Depth and Drainage Area



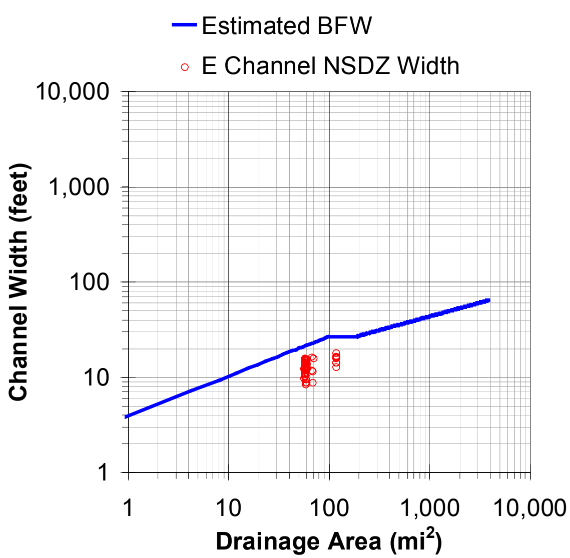
B Channel Regression Analysis for Average W:D = 18.6

n = 4,032, R^2 = 0.60
Se = 7.8 m (25.5 ft)
F Statistic = 146
Significant at 0.05



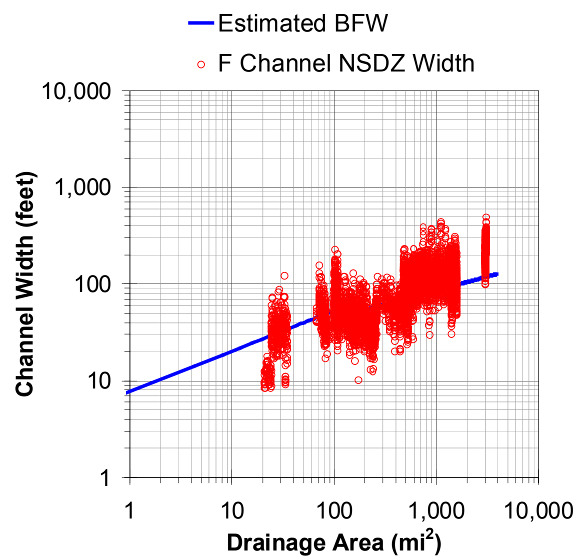
C Channel Regression Analysis for Average W:D = 29.8

n = 10,547, R^2 = 0.54
Se = 12.3 m (40.4 ft)
F Statistic = 581
Significant at 0.05



E Channel Regression Analysis for Average W:D = 7.1

n = 56, R^2 = 0.20
Se = 10.0 m (32.8 ft)
F Statistic = 74
Not Significant at 0.05



F Channel Regression Analysis for Average W:D = 27.6

n = 7,373, R^2 = 0.55
Se = 12.3 m (40.4 ft)
F Statistic = 883
Significant at 0.05

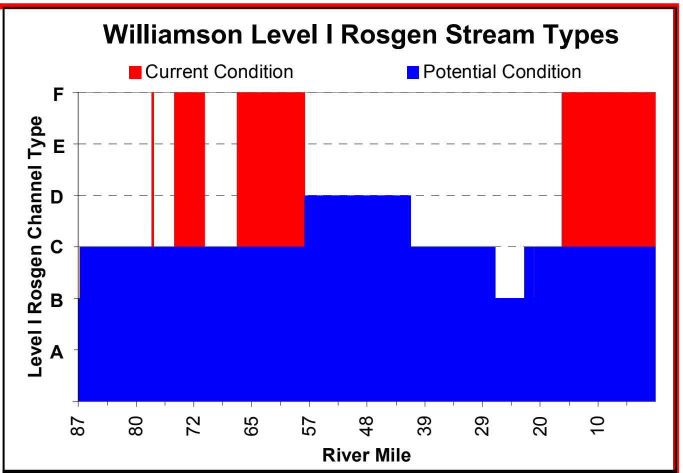
Step 10

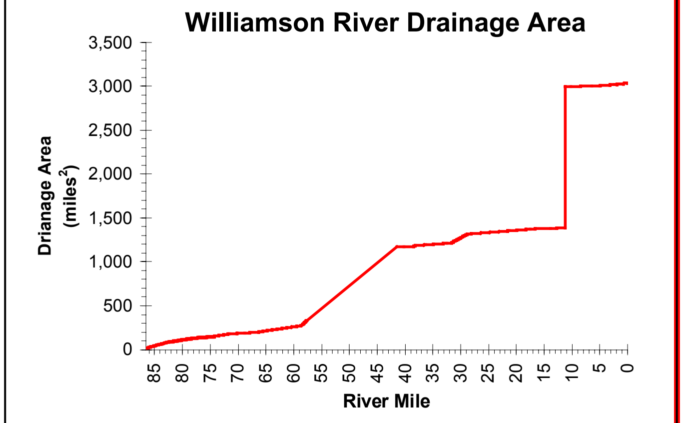
Develop Potential Channel Width as a Function of Stream Type, Width to Depth Ratios and Drainage Area

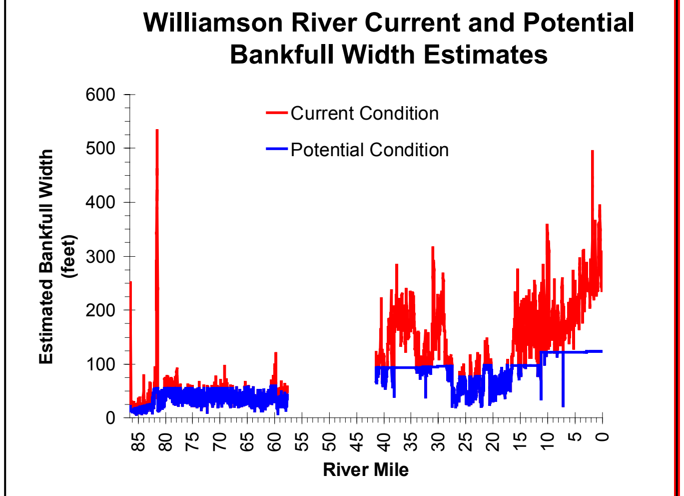
Rosgen (1996) outlines a methodology for analyzing channel evolution. Drawing from this methodology ODEQ estimated the potential for change with stream channel types. A, B, C and E stream types are considered in a stable condition with little chance for change to another stream type. D channels are braided, resulting from natural and/or human disturbance process. In some cases D channels can change to C or E stream types provided sediment supply and stream morphology allows. All F stream types are considered below potential and changed to either C or E types, depending on the contributing drainage area.

Current Condition	Potential Condition
A	A
B	B
C	C or E
D	C, D or E
E	E
F	C or E

Using regional curve relationships for bankfull width (**developed in Step 9**) as a threshold condition, departures above this threshold become evident. Potential bankfull widths are developed by simply targeting bankfull width values at or below the regional curve threshold for the appropriate stream type. In essence the potential stream type and width to depth ratio is targeted.

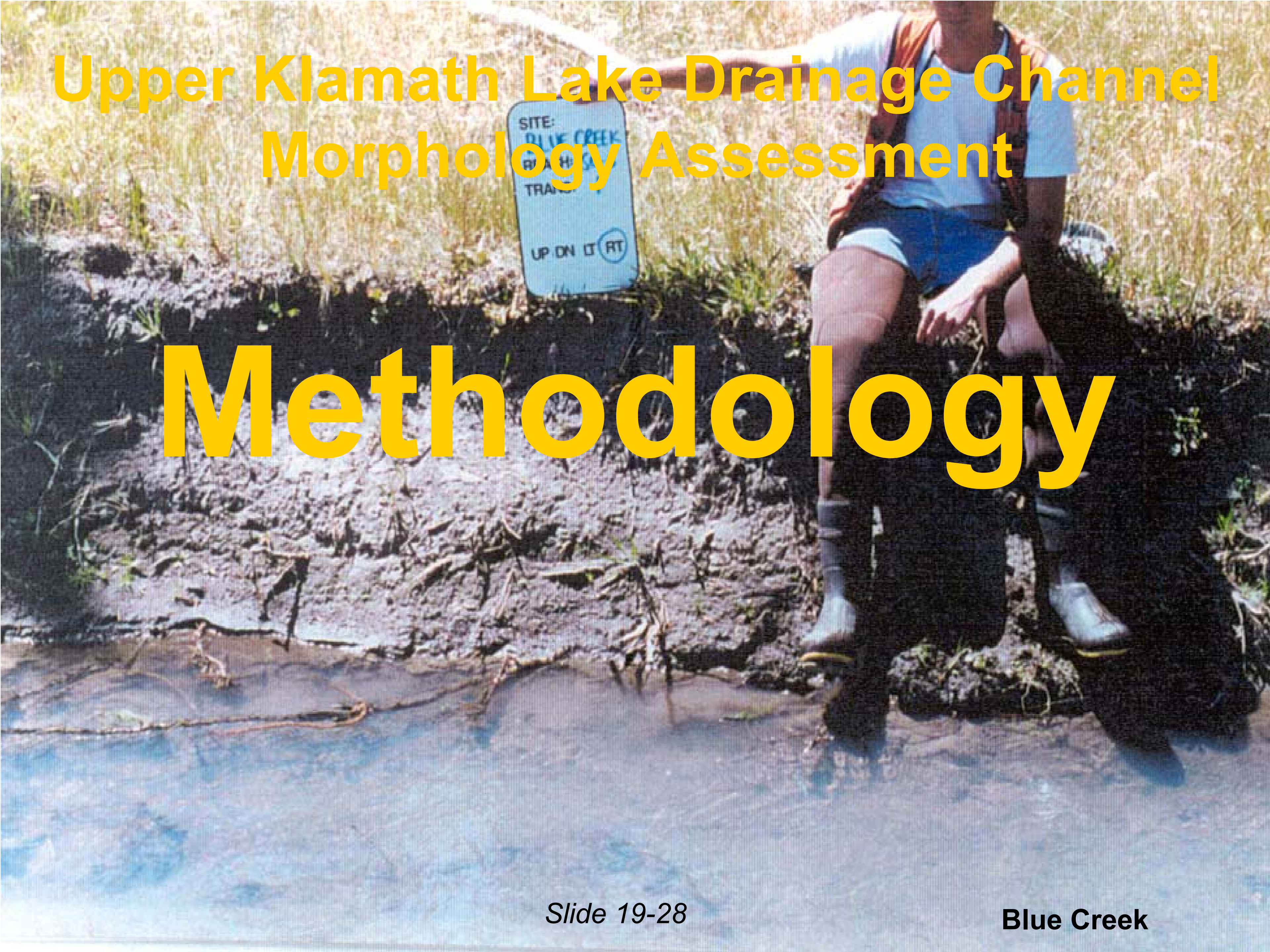






Upper Klamath Lake Drainage Channel Morphology Assessment

Methodology



Blue Creek

Williamson River

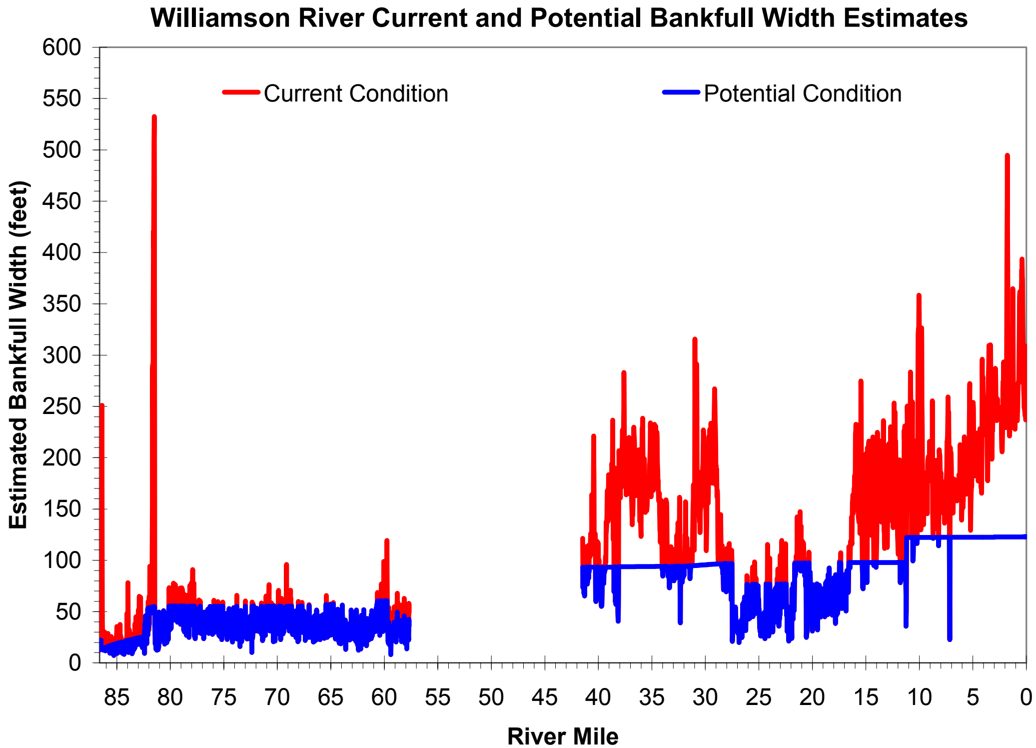
$$BFW = \sqrt{W:D \cdot A_{bf}}$$ (Rosgen, 1996)

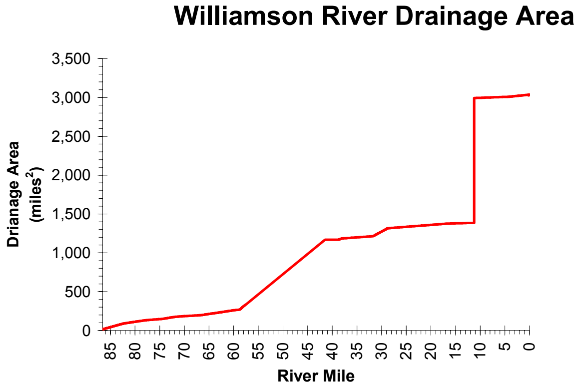
Where,

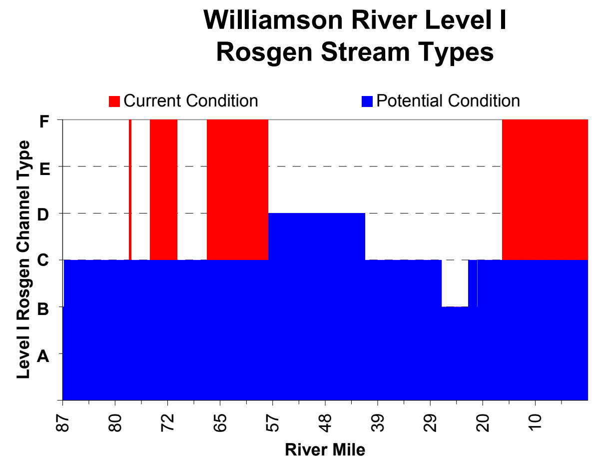
W:D - Estimated in **Step 9**

X_{Area} - Estimated in **Step 6**

Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
G	8.0





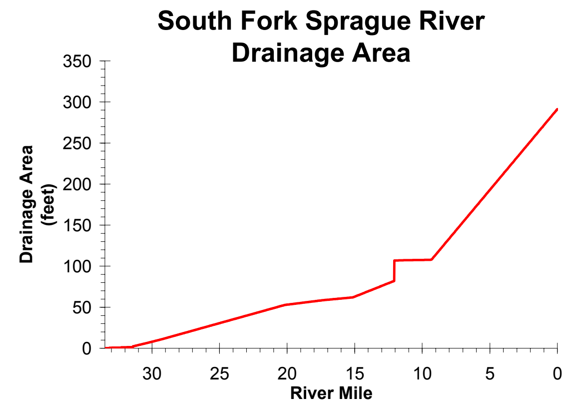


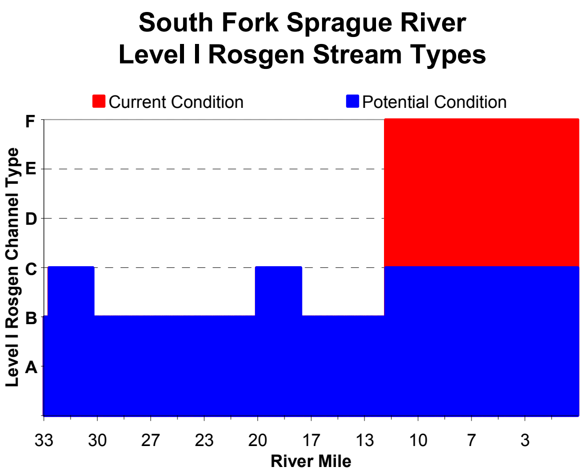
South Fork Sprague River

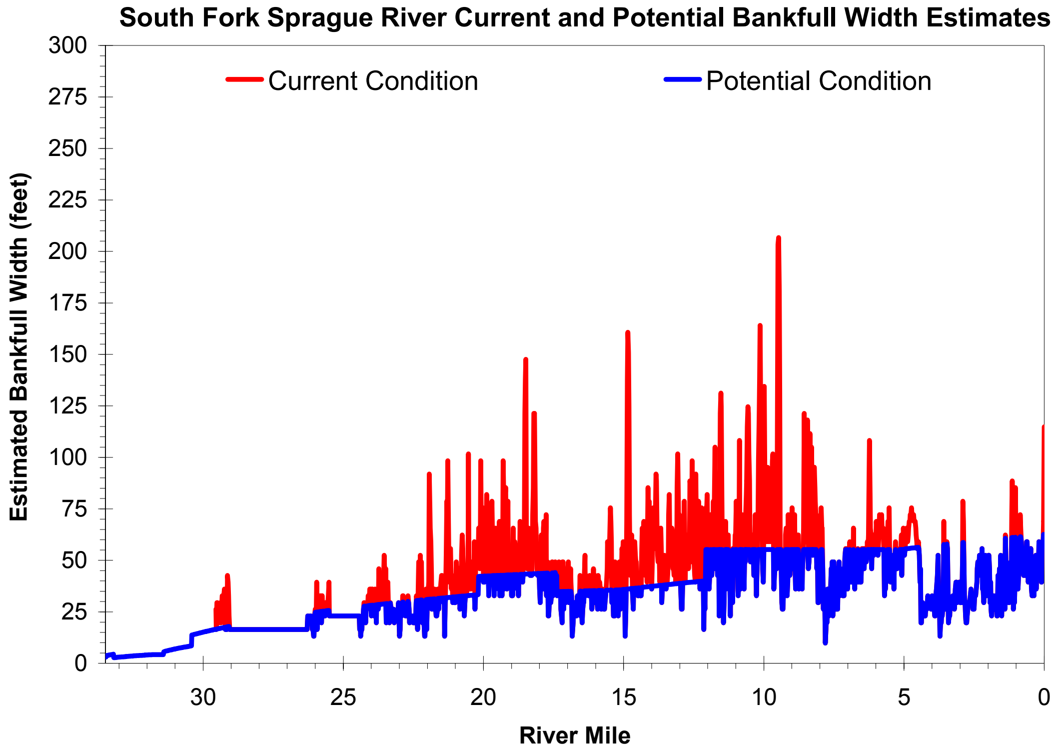
$$BFW = \sqrt{W:D \cdot A_{bf}}$$ (Rosgen, 1996)

Where,
W:D - Estimated in **Step 9**
X_{Area} - Estimated in **Step 6**

Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
G	8.0







North Fork Sprague River

$$BFW = \sqrt{W:D \cdot A_{bf}}$$ (Rosgen, 1996)

Where,

W:D - Estimated in **Step 9**

X_{Area} - Estimated in **Step 6**

Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
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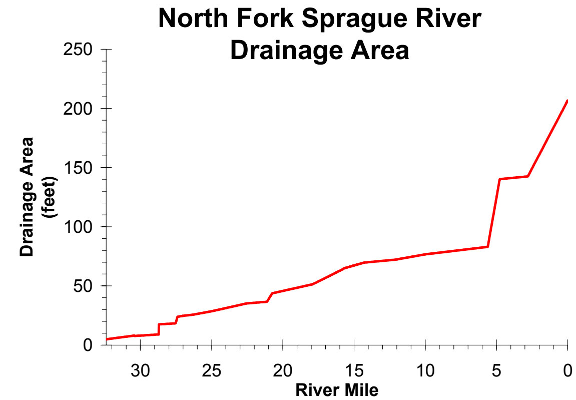
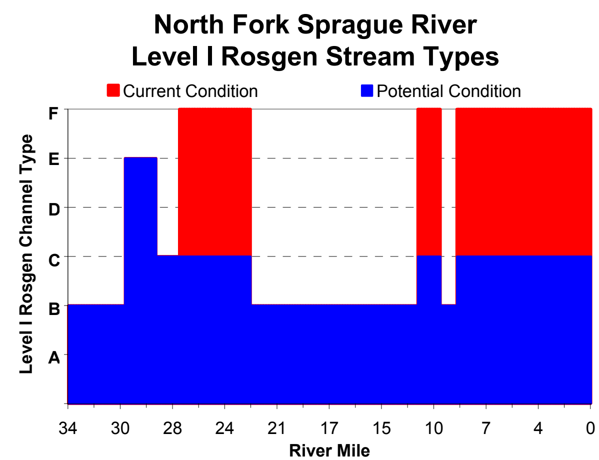
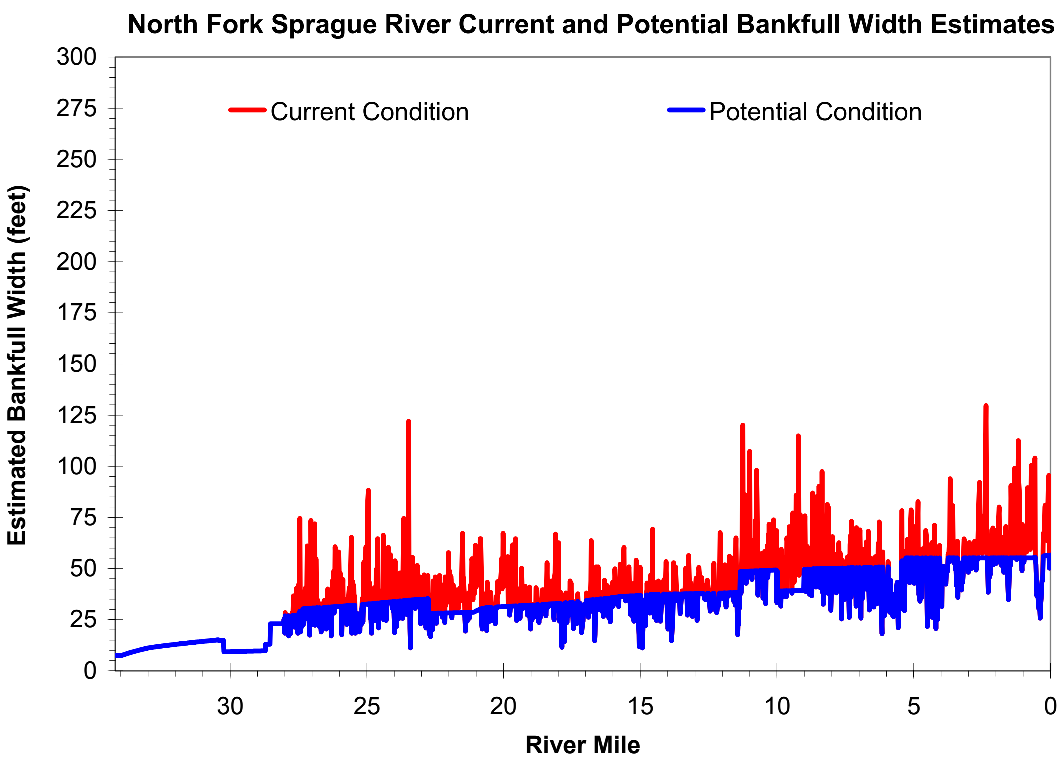






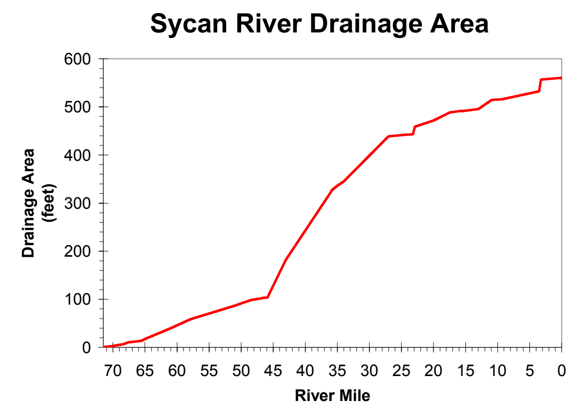
Slide 22-28

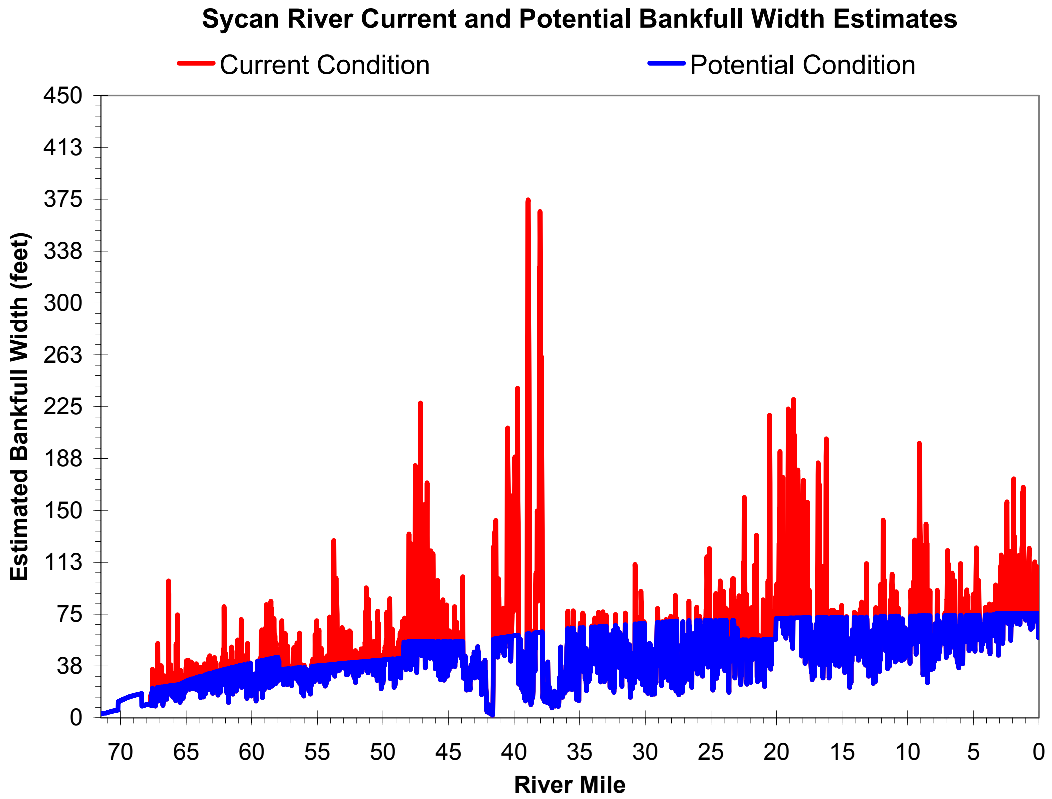
Sycan River

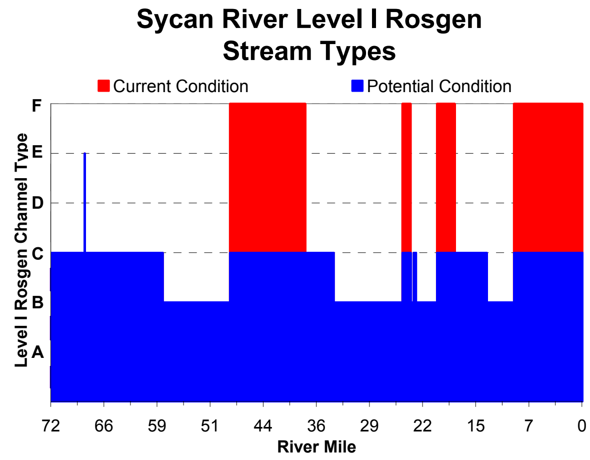
$$BFW = \sqrt{W:D \cdot A_{bf}}$$ (Rosgen, 1996)

Where,
W:D - Estimated in **Step 9**
X_{Area} - Estimated in **Step 6**

Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
G	8.0





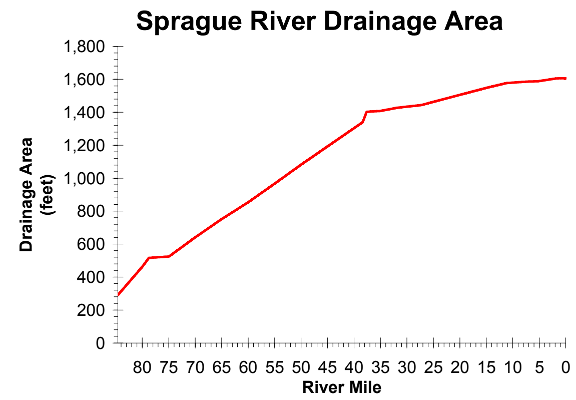


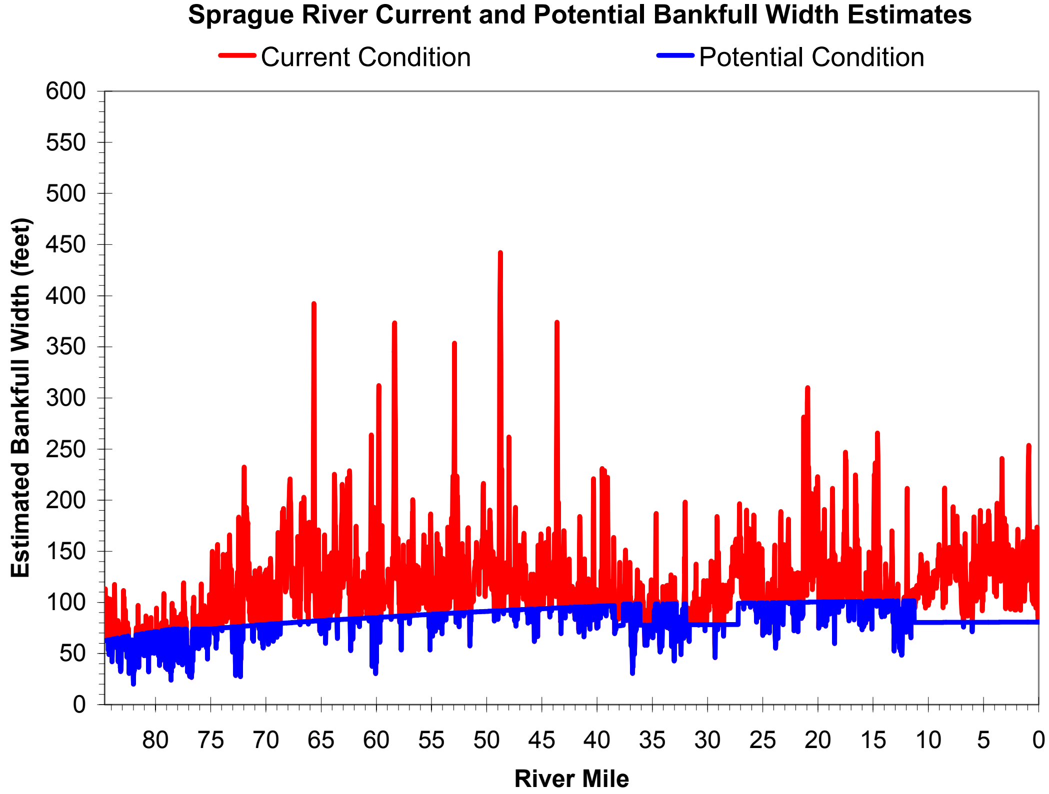
Sprague River

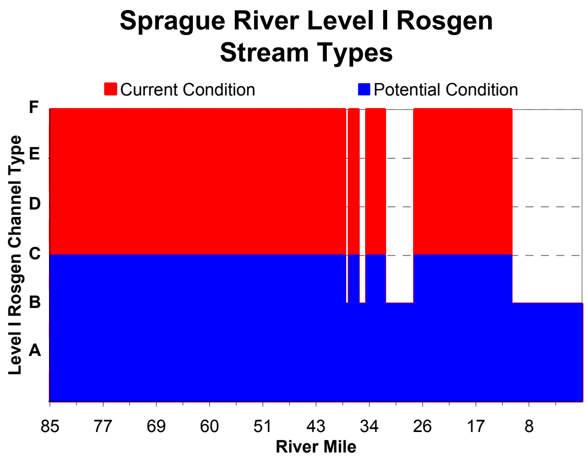
$$BFW = \sqrt{W:D \cdot A_{bf}}$$ (Rosgen, 1996)

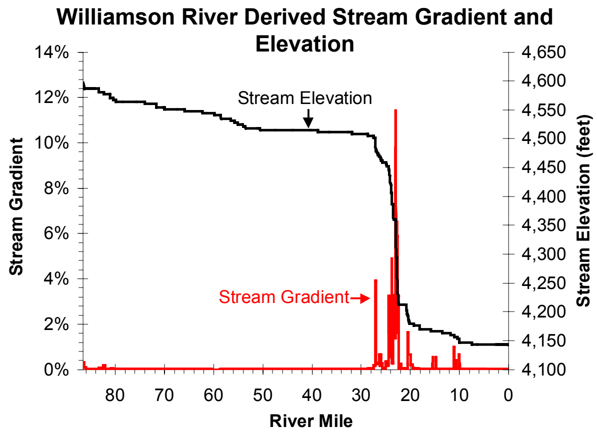
Where,
W:D - Estimated in **Step 9**
X_{Area} - Estimated in **Step 6**

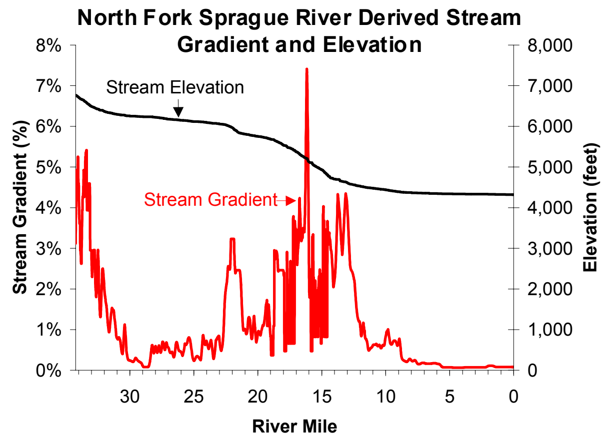
Level I Stream Type	Width to Depth
A	7.9
B	18.6
C	29.8
D	N/A
E	7.1
F	27.6
G	8.0

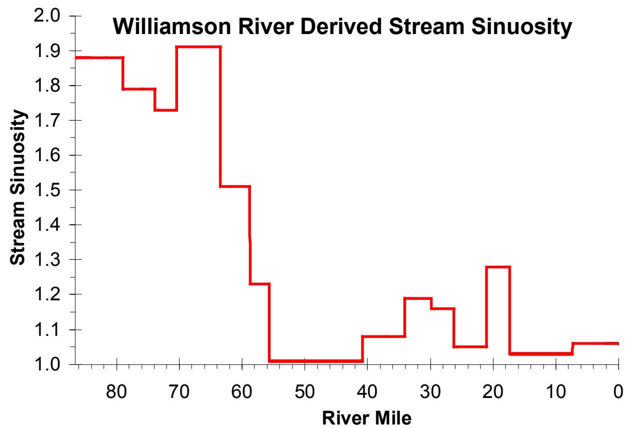


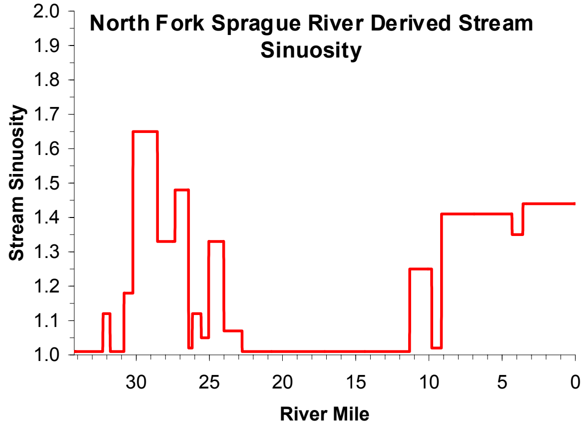


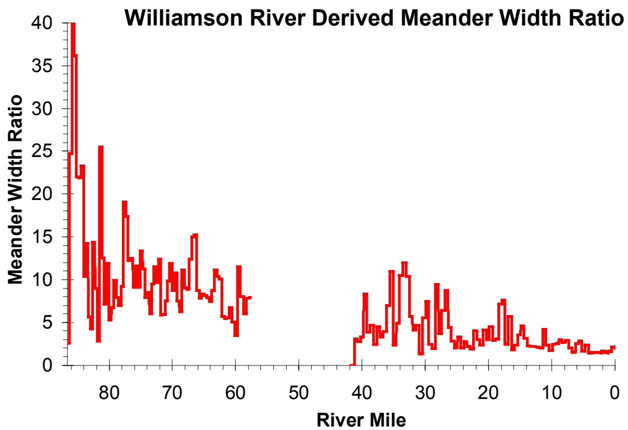


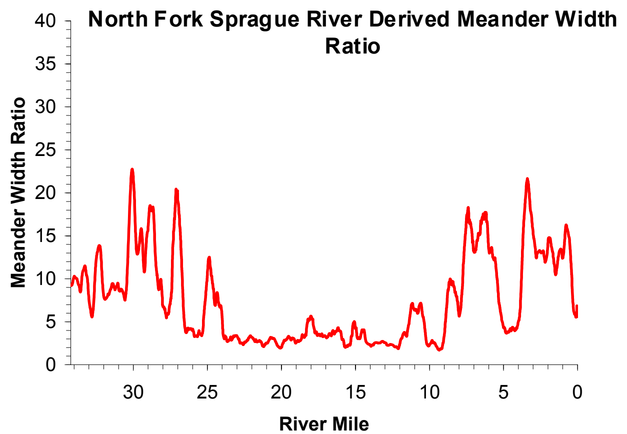

Williamson River Derived Stream Gradient and Elevation
Stream Elevation
Stream Gradient
Stream Gradient
Stream Elevation (feet)
River Mile


North Fork Sprague River Derived Stream Gradient and Elevation
Stream Elevation
Stream Gradient
Stream Gradient (%)
Elevation (feet)
River Mile


Williamson River Derived Stream Sinuosity
Stream Sinuosity
River Mile


North Fork Sprague River Derived Stream Sinuosity
Stream Sinuosity
River Mile


Williamson River Derived Meander Width Ratio
Meander Width Ratio
River Mile


North Fork Sprague River Derived Meander Width Ratio
Meander Width Ratio
River Mile

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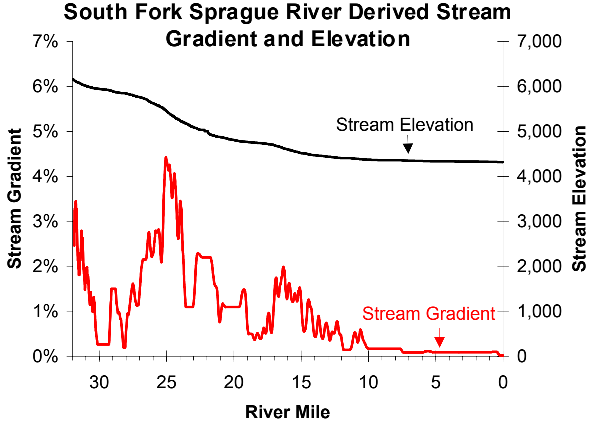
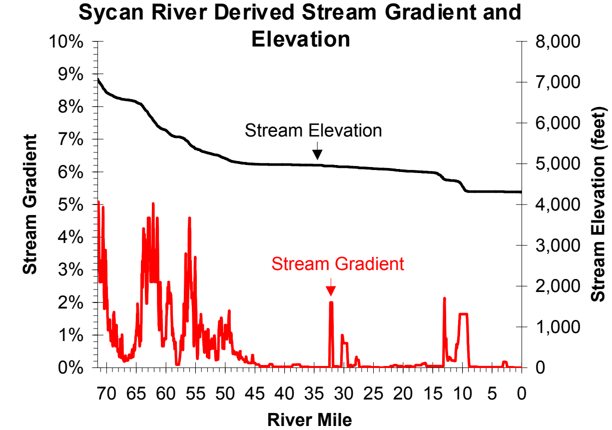
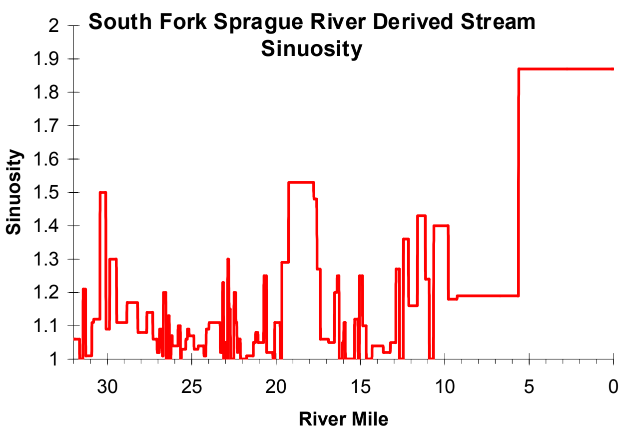
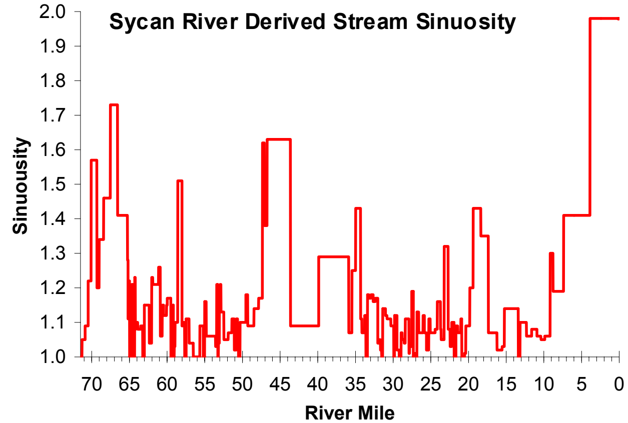
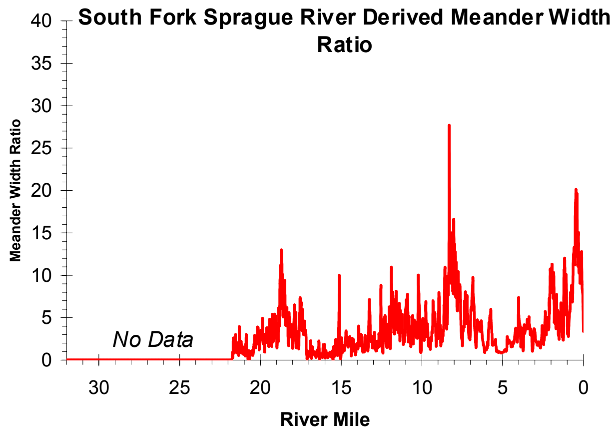
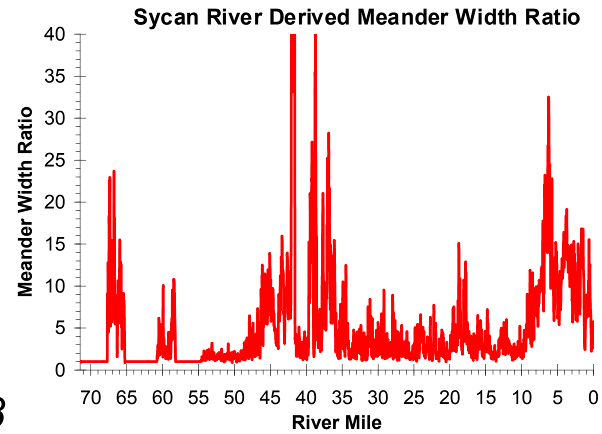

South Fork Sprague River Derived Stream Gradient and Elevation
Stream Gradient
Stream Elevation
River Mile
Stream Elevation
Stream Gradient
7%
6%
5%
4%
3%
2%
1%
0%
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
30
25
20
15
10
5
0


Sycan River Derived Stream Gradient and Elevation
Stream Gradient
Stream Elevation (feet)
River Mile
Stream Elevation
Stream Gradient
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

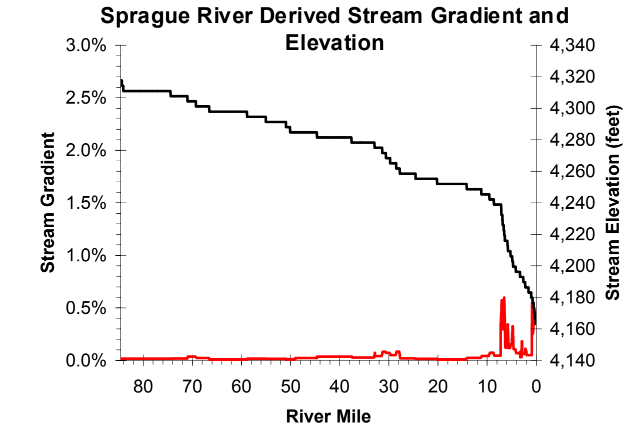

South Fork Sprague River Derived Stream Sinuosity
Sinuosity
River Mile
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
30
25
20
15
10
5
0

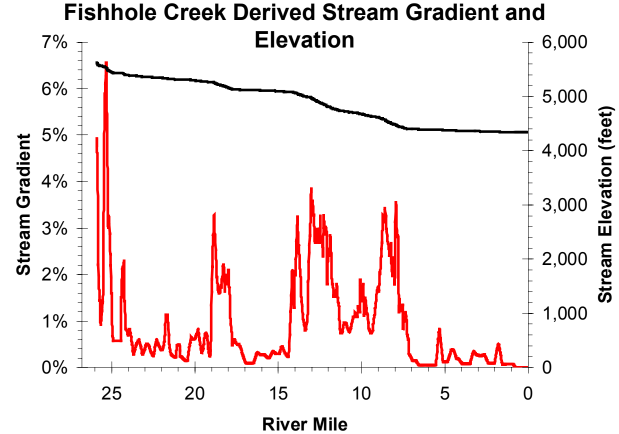

Sycan River Derived Stream Sinuosity
Sinuousity
River Mile
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

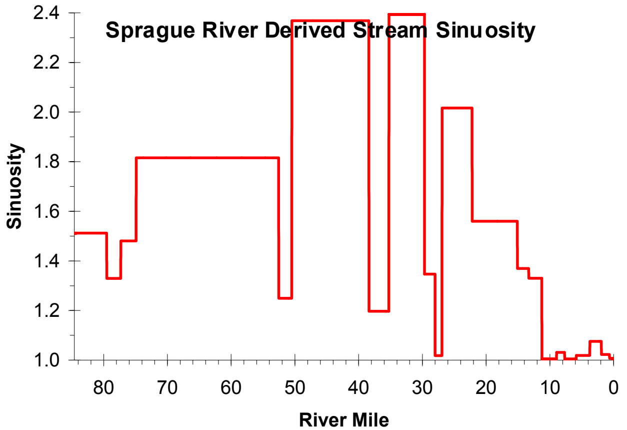

South Fork Sprague River Derived Meander Width Ratio
Meander Width Ratio
River Mile
No Data
40
35
30
25
20
15
10
5
0
30
25
20
15
10
5
0

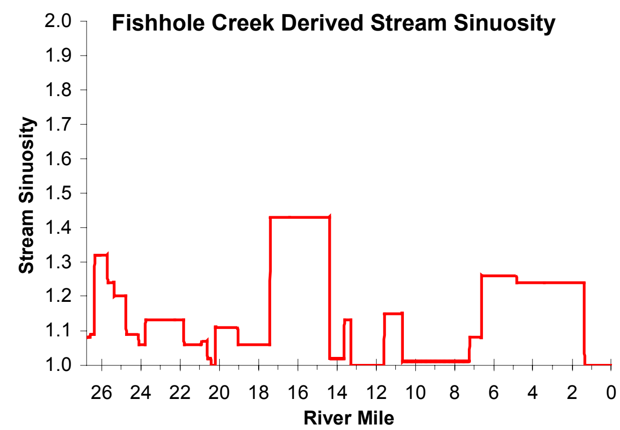

Sycan River Derived Meander Width Ratio
Meander Width Ratio
River Mile
40
35
30
25
20
15
10
5
0
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

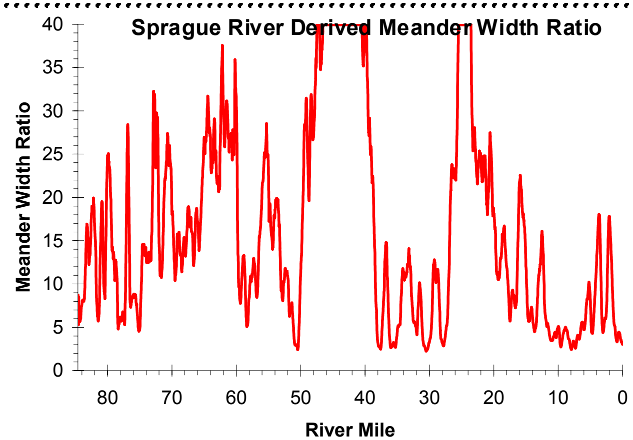
Slide 26-28


Sprague River Derived Stream Gradient and Elevation
Stream Gradient
Stream Elevation (feet)
River Mile


Fishhole Creek Derived Stream Gradient and Elevation
Stream Gradient
Stream Elevation (feet)
River Mile


Sprague River Derived Stream Sinuosity
Sinuosity
River Mile


Fishhole Creek Derived Stream Sinuosity
Stream Sinuosity
River Mile


Sprague River Derived Meander Width Ratio
Meander Width Ratio
River Mile

Slide 27-28

Topographic Shade Angles