DRAFT MIDDLE CALAPOOIA RIVER PROJECT IMPLEMENTATION PLAN

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EXECUTIVE SUMMARY

approximately 8 miles to the Sodom Dam site. Tasks completed during the reconnaissance included the following.

- Confirmation of the reach break delineation based on aerial photograph interpretation.
- Channel habitat unit classification and mapping.
- Bank stabilization structure and floodplain levee mapping.
- Bank erosion site mapping.
- Assessment of existing impaired and reference reach conditions.
- Photographic documentation of river corridor conditions.

Data collection sheets were completed and transferred into Microsoft Excel for processing. Spatial data were plotted in ArcGIS on recent aerial photos. Maps are included in Appendix A and Appendix B. Reconnaissance information was also used for preparing conceptual restoration, conservation, and stabilization plans.

Channel Habitat Unit Classification and Mapping

Channel habitat units were classified to evaluate habitat diversity in each of the four reaches. A laser rangefinder was used to measure habitat feature lengths. Habitat feature locations and extents were noted on air photo base maps. Habitat units were determined based on water velocity, turbulence, channel bed profile facet slopes, and water depth. The four primary features included riffles, runs, pools, and glides (Bisson et al. 1982). Riffles were defined as higher gradient sections of channel exhibiting surface turbulence. Runs were defined as the transition from the riffle into the pool. Although determining the length of runs was difficult due to elevated flows at the time of the survey, run features were characterized as channel sections with higher water velocities transitioning into slower water velocities marked by the start of the pool. Pools were the deepest habitat units and typically had the lowest water velocities. Glides were marked by an increasing channel bed elevation to the start of the subsequent riffle. Glides form the transition between the pool and riffle. Other sections of the river that lacked features associated with riffles and runs, were also noted as glides. Table X summarizes channel habitat unit features.

Table X. Characteristics of channel habitat features.

Habitat Unit	Surface Turbulence	Water Velocity	Water Depth	Bed Facet Slope	Fish Habitat Benefits
Riffle	High	Medium	Low	Negative	Food production
Run	Medium	High	Medium	Negative	Feeding areas
Pool	Low	Low	High	Negative	Resting and feeding areas
Glide	Low	Low	Medium	Positive	Resting and feeding areas

Bank Stabilization Structure and Floodplain Levee Mapping

Bank stabilization structures and floodplain levees were noted on the air photo base maps. Data collected by RDG were combined with information provided by the Calapooia Watershed Council to produce a bank stabilization GIS layer. Data were compiled by reach for comparisons. Stabilization information was reviewed as part of the reach review. Table X

1.0 INTRODUCTION

1.1 Purpose of Effort

The Calapooia Watershed Group (CWG) retained River Design Group, Inc. (RDG) to complete the *Middle Calapooia River Project Implementation Plan* (Plan). The Plan scope of work included reviewing existing information, completing a field assessment, and identifying potential restoration, conservation, and/or resource protection opportunities on the Middle Calapooia River between the former Brownsville Dam site and the Sodom Dam, an approximately 8 mile reach.

The purpose of the Plan is to provide an view of river corridor conditions and recommendations for restoring, conserving, and protecting resources in the study area. RDG and CWG developed the following project objectives for the Plan.

1) Assess existing river corridor conditions in the 8 mile project reach.
2) Address existing river corridor conditions that may affect migratory fish species.
3) Identify potential restoration sites and provide typical treatments for improving fish habitat.
    a. Treatments should: 1) focus on reducing, or at least not increasing, water temperatures, 2) increase channel complexity, and 3) take into account multiple native fish species and their life histories, as well as other rare or critical species including the western pond turtle.
4) Provide treatment approaches for addressing severe bank erosion that is currently impacting landowners in the reach.

Field surveys and remote sensing were used to evaluate the river. Data collection and analyses were structured to achieve the assessment objectives.

2.0 METHODS

The following section outlines RDG's methods for evaluating the existing river corridor conditions and preparing the conceptual design plans.

2.1 Field Survey

RDG completed field data collection in October 2007 to characterize the stream corridor, channel habitats, sediment sources, and bank stabilization structures. Field data collection methods included a reconnaissance-level river walk-through, channel surveys, discharge measurements, and channel bed material characterization. The field surveys characterized typical channel conditions in each of the four reach that were established. Project reaches were delineated according to river conditions typified by the channel and valley morphologies. The following sections outline the employed methods.

2.1.1 River Reconnaissance

RDG completed a river reconnaissance on the Middle Calapooia River on October 22 and 23, 2007. The reconnaissance began at the former Brownsville Dam site and continued downstream photographs were taken at each surveyed cross-section and to characterize the reach. Ground photographs are stored on RDG's Corvallis office network and are provided on a DVD at the end of this report.

2.1.3 Hydraulic Modeling

Hydraulic modeling was completed to evaluate channel hydraulics in the four reaches. At-a-section modeling was completed using WinXSPro (Hardy et al. 2005). Data used in the models included the respective channel cross-sections, the low discharge and bankfull discharge water surface slopes, and the D84 particle size. Discharge measurements were completed to assist in model calibration.

2.2 Remote Sensing

ArcGIS programs were used to develop field base maps and visualization figures. Programs included ArcGIS Version 9.1 (ESRI 2005a) and ArcGIS extensions, Spatial Analyst (ESRI 2005b) and 3D Analyst (ESRI 2005c). Channel plan form measurements were based on air photo interpretation. Spatial data were acquired from multiple state and federal agency sources.

2.3 Stream Classification

The Rosgen stream classification system was used to characterize physical features of the Calapooia River. The classification system is useful as a communication tool to convey typical channel conditions exhibited by a river. Important morphological features used to classify a river include the following variables.

- Entrenchment ratio (width of flood-prone area to width of bankfull channel)
- Width-to-depth ratio (bankfull width to mean bankfull depth)
- Dominant channel materials
- Slope
- Sinuosity (ratio of stream length to valley length)

The channel bankfull slope, width, mean depth, maximum depth, and floodprone width; and channel bed sediment were surveyed in the field. The channel sinuosity was measured using air photos. The Rosgen stream classification system uses these variables to delineate stream reaches into major stream types broken into alpha-numeric codes. Major stream types are given letters from A to G with each stream type defined by common physical characteristics. Numerals are added to the letter to denote the median particle (D_{50}) of a reach-averaged pebble count. Stream types are typically used to label stream reaches that are either 20 bankfull widths or two meander sequences in length. Smaller subreaches may be labeled as stream type inclusions. The following section provides a general description of the characteristics of the major Rosgen stream types found within the Calapooia River study area.

Rosgen B Stream Type

Rosgen B stream types are moderately steep (between 2 and 4 percent), with rapids and riffles common and scour pools irregularly spaced. Pools are commonly pocket pools rather than more expansive pools typically associated with outside meanders. These stream types are moderately entrenched (narrow floodplain relative to the bankfull channel width – 1.4 to 2.2), with moderate width-to-depth ratios (>12) and sinuosity (>1.2). Vegetation has a moderate influence in summarizes types of bank stabilization and flood levee treatments that were encountered during the field reconnaissance.

Table X. Typical bank stabilization and floodplain levee treatments encountered on the Calapooia River.

Treatment	Location	Typical Materials	Typical Influence of River Corridor
Bank Riprap	Streambank	Angular rock	Limits channel migration, may promote channel bed scour
Large Wood Placement	Streambank	Angular rock, wood	Limits channel migration, may promote channel bed scour, fish habitat enhancement
Spurs	Streambank	Angular rock	Bank stabilization, may promote channel bed scour
Barbs	Streambank	Angular rock	Bank stabilization, may promote channel bed scour
Levees	Floodplain	Rock, gravel, soil	Limit floodwater extent, confine river flows

Bank Erosion Site Mapping

Prominent bank erosion sites were noted on the air photo base maps and photographed. Due to the extensive banks stabilization in the study area, few bank erosion locations were identified. A bank erosion GIS layer was produced.

Impaired and Reference Conditions

Typical river corridor conditions were noted during the reconnaissance. Typical impaired condition sections of the river were noted by stabilized banks, low habitat diversity, infrequent large wood, and low floodplain habitat complexity. Reference sections of the river generally had dynamic channel conditions typified by abundant large wood, high habitat diversity, and well-developed floodplains.

2.1.2 Channel Surveys

Channel surveys were completed with a total station and survey laser. Survey data collection followed USFS procedures (Harrelson et al. 1994) and included channel cross-sections and profiles. Surveys were completed at both new sites and formerly established survey locations installed by the Natural Resources Conservation Service (NRCS). Channel survey data collected in 2007 were compared to earlier cross-section data collected by NRCS.

Survey data included cross-sections, longitudinal channel profile, discharge measurement, pebble counts, and ground photos. Data were collected to characterize terrace, floodplain, bankfull, water surface, and thalweg features. Additional features were also collected if deemed important for characterizing the reach. Channel thalweg measurements were generally collected at changes in the channel bed elevation or habitat features. Water surface measurements were collected at changes in the water surface slope and corresponding habitat features. Total station survey data were corrected using AutoCAD Land Development Desktop 2007/2008 (Autodesk 2007).

Pebble counts were collected to characterize the channel bed sediment (Wolman 1954). Pebble count data were imported into RiverMorph for storage, processing, and analysis. Multiple

6	Silt	< 0.062

The Calapooia River is a gravel bed river. Most of the reaches classify as Rosgen C4 or Rosgen B4 stream types. Shorter sub-reaches or inclusions have a bedrock channel bottom.

3.0 Calapooia River Watershed Overview

Hydrology

Table X. The flood frequency for the Calapooia River based on a former gaging station in the watershed corrected for the watershed area in the study area (Gage Station Estimate), and regional relationships (Prediction).

Return Period (years)	Gage Station Estimate			Prediction		
		95% Confidence			95% Confidence	
	Peak Flow (dfs)	Lower (cfs)	Upper (cfs)	Peak Flow (dfs)	Lower (cfs)	Upper (cfs)
2	5,500	4,980	6,070	6,940	3,720	12,900
5	7,920	7,120	8,980	10,200	5,510	19,000
10	9,550	8,460	11,100	12,500	6,660	23,300
20	11,100	9,710	13,200	14,600	1,170	27,800
25	11,600	10,100	13,800	15,300	8,030	29,200
50	13,200	11,300	16,000	17,400	8,980	33,900
100	14,700	12,400	18,200	19,600	9,880	38,800
500	18,300	15,100	23,500	24,600	11,800	51,200

4.0 Stream Corridor Conditions

4.1 River Corridor Overview

The 8 mile study area was delineated into four reaches based on channel and valley morphologies. Reach 1 extends from the former Brownsville Dam site to a change in stream type. Reach 2 extends through the Town of Brownsville. Reach 3 begins downstream of Brownsville Park and continues to a change in stream type. Reach 4 extends downstream to the Sodom diversion dam. Table X includes a reach summary.

Table X. Reach dimensions and characteristics for the Calapooia River study area.

Reach	Dominant Stream Type	Channel Length (miles)	Valley Length (miles)	Channel Sinuosity	Defining Characteristics
Reach 1	Rosgen C4	2.61	1.96	1.33	Sinuous channel, well-developed floodplain

determining channel stability in the Type B reaches. These B channel types are characterized by low to moderate sensitivity to disturbance and low streambank erosion. Fish habitat in B stream types is often associated with large woody debris that contributes to scour pool formation and cover (Rosgen 1996). Using the Montgomery and Buffington classification system (1997), B stream types are defined as plane bed morphology streams.

Reach 2 and Reach 4 in the Calapooia River study area are classified as Rosgen B stream types.

Rosgen C Stream Type

Rosgen C streams have a lower gradient, are slightly entrenched (>2.2), have moderate to high (>12) width-to-depth ratios, high sinuosity values (>1.4), and are characterized by riffle/pool sequences. These channels have characteristic point bars and broad, well-defined floodplains. Vegetation influences channel stability more so than in B stream types. When vegetation is disturbed and removed, C stream types are sensitive to both lateral (bank) and vertical (down-cutting) erosion. Natural sediment supply is moderate to high except in those areas where streambanks are well vegetated. These streams are highly sensitive to changes in sediment and stream flow (Rosgen 1996). Using the Montgomery and Buffington classification system (1997), C stream types are defined as riffle-pool morphology streams.

Reach 1 and Reach 3 in the Calapooia River study area are classified as Rosgen C stream types.

Rosgen F Stream Type

The F stream type occurs sporadically throughout the study area in locations where the floodplain is restricted by topography, levees, or where the stream has a more unstable form as a result of disturbances. The F stream types are deeply entrenched, with most flood flows confined to the channel. This stream type is typically creating a new floodplain at a lower elevation than the historical floodplain. This process leads to high levels of bank erosion, bar development, and sediment transport. Because of the entrenchment and high width-to-depth ratio, velocities can reach relatively high levels at flood flows because the floodplain is not developed enough to dissipate energies. Stream power is thus greater and may lead to increased damage to streambanks and the channel bed.

Rosgen Stream Type Numerical System

The median channel bed sediment particle size is used to allocate a numerical value to the stream type. The numbering system spans from 1 to 5, with increasing values representing a fining of the median particle size. A bedrock bed is defined as a 1, a silt bed is defined as a 6. Table X includes the numerical values and the associated particle size ranges.

Table X. Rosgen stream classification system numerical values, common sediment class name, and associated particle size distribution.

Numerical Value	Sediment Class Name	Sediment Class Size Range (mm)
1	Bedrock	Bedrock
2	Boulder	256 – 2,048
3	Cobble	64 – 256
4	Gravel	2 – 64
5	Sand	0.062 – 2

Channel habitat unit diversity in the reach reflects the range of fish habitat conditions found in Reach 1. Diverse habitats, frequent large wood, side channels, and extensive riparian vegetation contribute to fish habitat diversity in the reach. The channel habitat units provide the range of instream conditions to support food production, fish growth, and spawning. Instream large wood provides cover and varied flow paths beneficial for fish foraging and resting. Off-channel habitats provide juvenile rearing habitat during all flows, and are especially important resting areas during high water events. The multi-age riparian community provides wood and leaf litter to the stream creating habitat and the basic nutrients for the aquatic community.

4.2.1 Historical Planform Analysis

A time series air photo analysis was completed to evaluate the channel planform geometry over three periods; 1936, 1967, and 2005 (Table X). Planform metrics suggest the channel in 2005 is more similar to the 1936 condition relative to the 1967 condition. The 1964 flood event may have affected the channel planform captured in the 1967 photograph. The average radius of curvature was lowest in 1937 and highest in 1967. Radius of curvature measurements were least variable in 2005 and most variable in 1967. The average meander length was greatest in 1967 and lowest in 1936. Meander lengths were most variable in 2005. The channel beltwidth was greatest in 2005 and lowest in 1967. Channel sinuosity was similar in 1936 and 2005; the 1967 channel had the lowest sinuosity.

Table X. Channel planform metrics from the historical air photo analysis for Reach 1.

Year	Metric	Radius of Curvature (ft)	Meander Length (ft)	Beltwidth (ft)	Sinuosity
1936	Mean	264	1,555	665	1.26
	1 SD	144	279	136	
1967	Mean	370	1,685	620	1.15
	1 SD	190	304	267	
2005	Mean	344	1,620	760	1.28
	1 SD	102	344	244	

The channel metrics suggest the 1936 was characterized by a relatively tight planform with the shortest radius of curvature and meander length measurements, and a moderate beltwidth. The channel planform therefore reflected frequent, short pools. The 1967 metrics suggest the river planform was more elongated compared to the 1936 planform. The radius of curvature and meander lengths increased. The average beltwidth distance and lower sinuosity suggest a straighter active channel inn 1967 relative to 1936. Lower radius of curvature and meander length values in 2005 suggest a trend back towards the 1936 conditions. However, the higher average channel beltwidth and sinuosity suggest the Calapooia River in Reach 1 expanded laterally from 1967 to 2005. The 2005 channel is eroding into lateral high terraces that bracket the active channel corridor, in five locations.

4.2.2 Channel Survey Results

Channel surveys were completed in Reach 1 in March 2007 as part of the Brownsville Dam removal project. Ten cross-sections were completed through the dam reach. Four cross-sections

Reach 2	Rosgen B4c	1.47	1.30	1.14	Narrow beltwidth and valley bottom
Reach 3	Rosgen C4	1.61	1.17	1.38	Dynamic channel, well-developed floodplain
Reach 4	Rosgen B4c	2.29	1.74	1.32	Confined channel, narrow floodplain
Total		8.0	6.17	1.30	Confined channel, narrow floodplain

4.2 Reach 1

Reach 1 begins at the former Brownsville Dam site. The channel transitions from a Rosgen B4 stream type in the vicinity of the former dam, to a Rosgen C4 stream type 1,600 ft downstream from the former dam location. Reach 1 extends 2.61 miles to a change in the dominant stream type marking the start of Reach 2. The channel morphology is characterized by alternating riffle-pool sequences. Riffles are typically steep with short runs into deep pools. Glides tend to be relatively long and broad.

The floodplain morphology in the reach is influenced by the valley bottom width and river processes. At the beginning of the reach in the B stream type section, the valley bottom is narrow. The floodplain is defined by a narrow depositional feature on the north side of the river. Riparian vegetation is dominated by multiple age classes of willows. Mature cottonwoods and Oregon ash form the overstory on the outside of the meander. Bank erosion on the outside of the meander is recruiting mature large wood to the river.

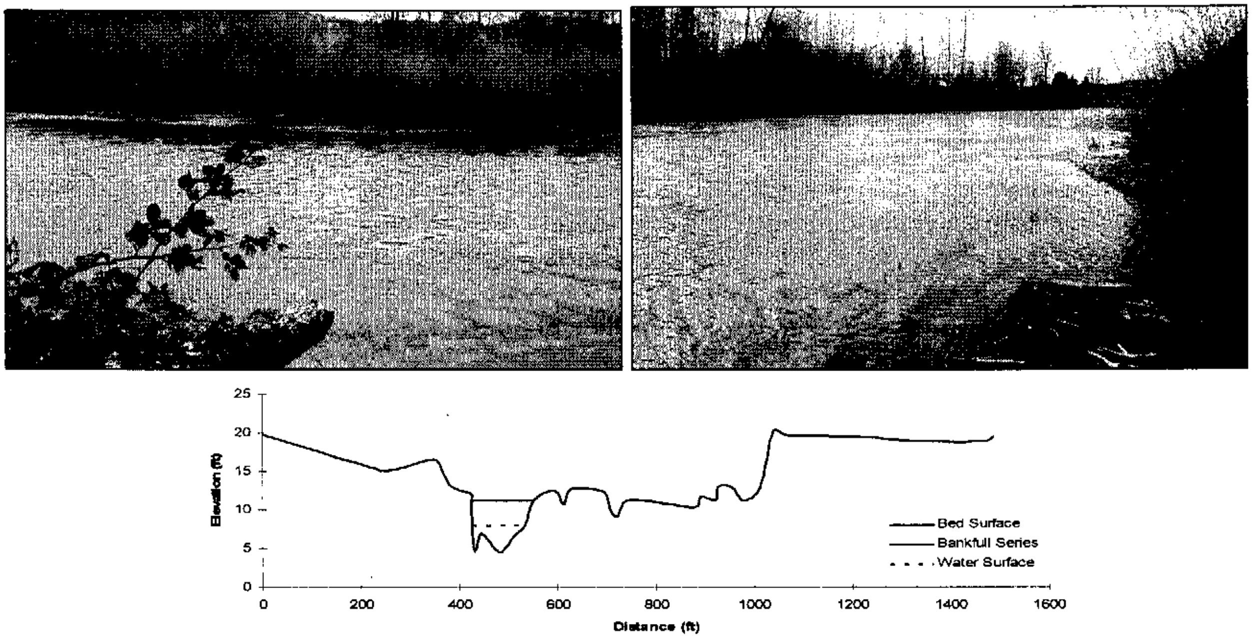
The floodplain broadens with the expanding beltwidth marked by the retreating high terraces. Through this transition, the Calapooia River moves from a B stream type to a C stream type. Point bars become more expansive with a more diverse floodplain community. The floodplain exhibits greater development with overflow channels, downed large wood, and a wider range of vegetation age classes. Mature cottonwoods are common on older floodplain surfaces. Younger age classes populate more recent depositional surfaces with the youngest vegetation bordering the active channel. Striations in the point bar vegetation community suggest both preferential flow routes and lateral meander migration patterns.

Reach 1 had the largest number of habitat units (71) of the four reaches. Glide habitats were the most common and also accounted for the greatest channel length. Pool habitats were the least common and also comprised the shortest channel length. Habitat unit summary statistics are presented in Table X. Figure X in Appendix A presents the distribution of habitat units in all four reaches.

Table X. The habitat unit summary for Reach 1.

Habitat Unit	Channel Length (ft)	Percent of Total Length	Number of Units	Percent of Total Units
Glide	4,826	34.5%	22	31.0%
Pool	1,336	9.5%	11	15.5%
Run	3,416	24.4%	17	23.9%
Riffle	4,429	31.6%	21	29.6%
Total	14,007	100.0%	71	100.0%

Figure X shows the cross-section at Sta. 29+00. The cross-section was located in the transition from the glide to a riffle. Similar to the cross-section at sta. 6+00, an inset floodplain is located adjacent to the baseflow channel. However, the distance between the terraces bracketing the channel beltwidth is over 1,000 ft. This distance compares to a width of only 560 ft at the cross-section at Sta. 6+00. Flatter channel slopes, lower water velocities and shear stress, and more diverse floodplain morphologies are typically associated with a broadening of the channel beltwidth. The undulations of the floodplain shown in Figure X show the multiple sidechannels and swales that are located on the floodplain north of the baseflow channel. Focusing restoration efforts on these areas of the stream corridor is suggested for enhancing juvenile fish rearing habitat and refugia.



Feature	Width (ft)	Area (ft²)	Mean Depth (ft)	Maximum Depth (ft)
Glide	126.7	577.9	4.6	6.6

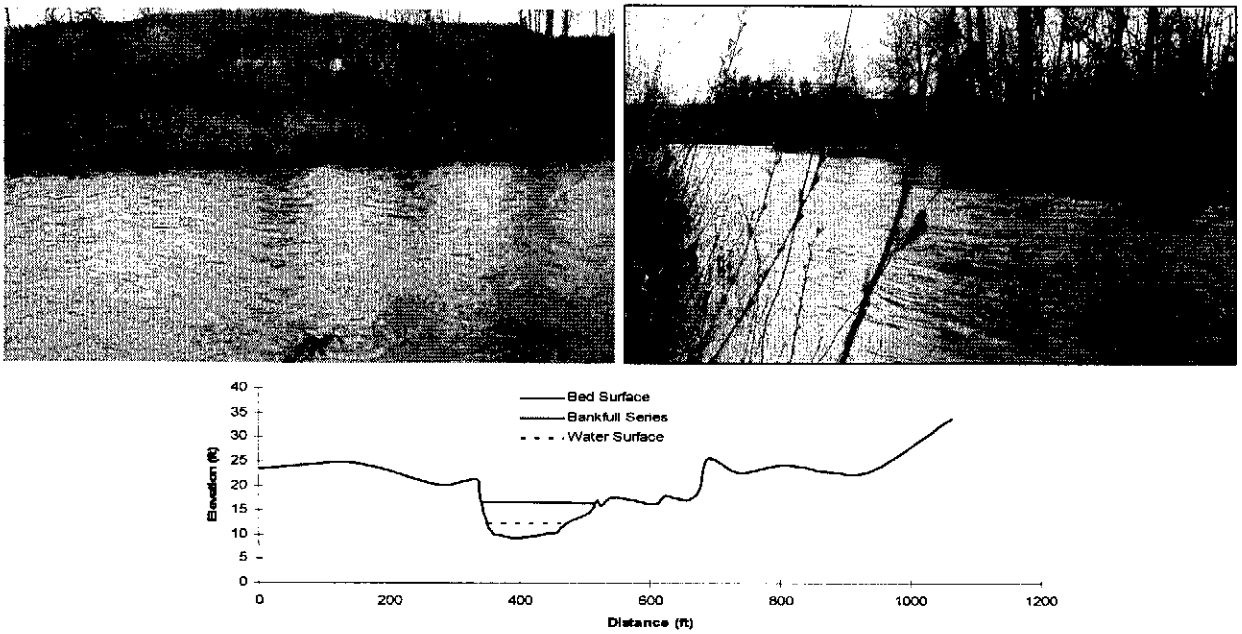
Figure X. The cross-section at Sta. 29+00 in the Rosgen C4 stream type portion of Reach 1. The upper left photo shows the right floodplain noted by the flat in the right portion of the cross-section diagram. The upper right photo is a view down river towards the left bank. The beltwidth is almost twice as wide at Sta. 29+00 compared to Sta. 6+00, a Rosgen B4c stream type.

were surveyed upstream from the dam, six sections were completed downstream from the dam. Pebble counts and bar samples were also collected to evaluate the channel bed sediment. The cross-sections downstream from the dam site characterized both the Rosgen B stream type and Rosgen C stream type portions of Reach 1. A subset of the cross-sections from both the B and C stream types was analyzed for this report (Table X).

Table X. Bankfull channel cross-section summary for Reach 1. The bankfull channel was delineated based on topographic breaks, sediment deposition, and vegetation patterns.

Reach	Station	Stream Type	Feature	Width (ft)	Area (ft²)	Mean Depth (ft)	Maximum Depth (ft)	Hydraulic Radius (ft)
Reach 1	6+00	B4c	Glide/Run	175.6	938.8	5.3	7.4	5.3
	10+00	B4c	Riffle/Run	211.9	777.0	3.7	6.5	3.6
	29+00	C4	Glide	126.7	577.9	4.6	6.6	4.5
	38+00	C4	Pool	169.5	715.9	4.2	6.7	4.2
	46+00	C4	Pool	375.9	1022.8	2.7	5.9	2.7

Figure X depicts the cross-section at Sta. 6+00. The photos capture the features surveyed in the cross-section. For example, the flat inset floodplain in the right portion of the channel cross-section immediately above the estimated bankfull elevation, is the willow surface in the upper left photograph. The low terrace that is shown forming the left bank in the cross-section figure is captured in the upper right photograph.



Feature	Width (ft)	Area (ft²)	Mean Depth (ft)	Maximum Depth (ft)
Glide/Run	175.6	938.8	5.3	7.4

Figure X. The cross-section at Sta. 6+00. The upper left photo shows the right floodplain noted by the flat in the right portion of the cross-section diagram. The upper right photo is a view up river towards the left bank.

The estimated bankfull discharge return interval for streams in western Oregon is 1.5-years (Castro 1997; Kuch 2000). The regional relation regression equation is Bankfull Discharge = 44.8*Drainage Area$^{0.918}$ (correlation coefficient $R^2 = 0.85$). Based on a drainage area of 152 square miles in the project area, the estimated bankfull discharge is 4,510 cfs. The Channel Capacity – Low Feature and Channel Capacity – High Feature each conveyed less than the predicted 1.5-year event of 4,510 cfs. However, given the variability inherent in relational equations and hydraulic modeling, the modeling results suggest the scour channel conveys close to the bankfull discharge. The floodway capacity modeling run suggests the floodway conveys nearly 52,000 cfs before the terraces are overtopped. This discharge is double the predicted 500-year event based on the discontinued stream gage station flood frequency analysis. Additional information that would be required to verify this result would include high stage water surface slopes and roughness estimates for the floodplain. In summary, the modeling results suggest the scoured channel conveys the approximate bankfull discharge and the floodway has the capacity to convey in excess of the 500-year event. Additional data and modeling would need to be completed to validate these results.

C Stream Type Modeling Results

Three modeling runs were completed for Sta. 29+00 (Table X). The Channel Capacity – Low Feature was the bankfull channel capacity with the bankfull elevation designated as the topographic break from the scoured channel to the vegetated floodplain. The Channel Capacity – High Feature was the bankfull channel and the floodplain. The floodplain at Sta. 29+00 has patches of vegetation but mainly has expanses of gravel and sand suggesting it is frequently inundated. The channel area more than doubled from the Low Feature to the High Feature cross-sections. The third modeling run was completed for the floodway capacity that included the active channel to the top of the terrace. Once floodwater eclipsed this elevation, it would access the high terrace (e.g., adjacent farmlands, roads). The modeling results are conceptual and would require additional detailed surveys to confirm hydraulic properties.

Table X. The hydraulic modeling results for three stages on the Calapooia River at Sta. 29+00.

Feature	Max Depth (ft)	Area (ft²)	Width (ft)	Hydraulic Radius (ft)	Slope	Mannings-n Value	Average Velocity (fps)	Discharge (cfs)	Shear Stress (lbs/ft²)
Channel Capacity - Low feature	6.60	664	289	2.3	0.0020	0.025	4.7	3,112	0.28
Channel Capacity - High feature	8.30	1,392	581	2.4	0.0020	0.034	3.5	4,900	0.30
Floodway Capacity	15.30	7,236	1,457	4.9	0.0001	0.025	1.9	13,372	

The Channel Capacity – Low Feature conveyed less than the predicted 1.5-year event of 4,510 cfs. The Channel Capacity – High Feature conveyed more than the estimated 1.5-year event but less than the 2-year event of 5,500 cfs. The Floodway Capacity run suggests the floodway contains up to the 50-year event before the lateral terraces are accessed. The floodway channel at Sta. 29+00 has substantially less capacity compared to the Sta. 6+00 cross-section due to the flatter floodplain slope in the C stream type reach. Similar to the Sta. 6+00 results, determining the appropriate flood stage water surface slope would improve the Floodway Capacity discharge estimate. In summary, the modeling results suggest the scoured channel and floodplain convey the approximate bankfull discharge and the floodway has the capacity to convey the 50-year event discharge. Additional data and modeling would need to be completed to validate these results.

Pebble count data from four sampling sites are presented in Table X. Pebble counts were completed downstream of the Brownsville Dam (Sta. 28+00 and 41+00) and at two locations in the same riffle at the Carbajal project location (Sta. 100+00). Channel bed sediment was relatively consistent through the reach.

Table X. Pebble count results for Reach 1. Stationing refers to the base maps provided in Appendix A, Figure 1.

Particle Class	Sta. 28+00 (mm)	Sta. 41+00 (mm)	Sta. 100+00-1 (mm)	Sta. 100+00-2 (mm)
D16	24	23	19	21
D35	35	35	37	36
D50	48	41	51	50
D65	67	63	64	66
D84	85	93	90	90
D95	120	120	110	120

4.2.3 Hydraulic Modeling Results

Two at-a-section hydraulic models were completed in Reach 1 to evaluate channel hydraulics and connection to the floodplain. Pebble count and discharge data were used to calibrate the model. The first model was completed for the cross-section surveyed at Sta. 6+00 in the B stream type reach. The second model was completed for the cross-section surveyed at Station 29+00 in the C stream type reach.

B Stream Type Modeling Results

Three modeling runs were completed for Sta. 6+00 (Table X). The Channel Capacity – Low Feature was the bankfull channel capacity with the bankfull elevation designated as the topographic break from the scoured channel to the vegetated floodplain. The Channel Capacity – High Feature was the bankfull channel capacity at a slightly higher topographic break from the scoured channel to the vegetated floodplain. The channel area increased 105 ft^2 from the Low Feature to the High Feature cross-sections. The third modeling run was completed for the floodway capacity that included the active channel to the top of the terrace. Once floodwater eclipsed this elevation, it would access the high terrace (e.g., adjacent farmlands, roads). The modeling results are conceptual and would require additional detailed surveys to confirm hydraulic properties.

Table X. The hydraulic modeling results for three stages on the Calapooia River at Sta. 6+00.

Feature	Max Depth (ft)	Area (ft^2)	Width (ft)	Hydraulic Radius (ft)	Slope	Mannings-n Value	Average Velocity (fps)	Discharge (cfs)	Shear Stress (lbs/ft^2)
Channel Capacity - Low feature	6.0	667	204	3.2	0.002	0.032	4.6	3,079	0.40
Channel Capacity - High feature	6.5	772	212	3.6	0.002	0.030	5.2	4,038	0.45
Floodway Capacity	15.4	5,253	1,073	4.9	0.002		9.9	51,917	0.61

Peterson and Reid (1984) describe three types of sidechannel habitats within a river floodplain; overflow channels, percolation-fed channels, and wall-based channels.

> *Overflow channels* are flood swales, and often-relict mainstem channels, that are directly connected to the main river channel during high flows or at all times. They are often very dynamic as a result of the periodic influx of water, sediment, wood, nutrients, and organic material from the main channel. Fish habitat associated with overflow channels is often unstable and typically prone to flooding and channel shifting though possibly on an infrequent basis. Periodic floods through these channels can help maintain their productivity, cleaning and redistributing spawning material and creating new habitat as other habitat is destroyed. Restoration of overflow channels might include reconnection of the channel to the mainstem and placement of habitat features within the channel. Without the natural hydrology and disturbance regime, keeping habitat functional often requires a high maintenance effort. The level of utilization may depend on the frequency of inundation by the mainstem. Entrapment of fish can occur if surface flow stops.
>
> *Perc channels* are relict river and/or flood channels and are primarily supplied by groundwater of the hyporheic zone. The hyporheic zone is the area beneath and next to a river channel that contains some proportion of water from the surface channel. Frequently, they are better protected from floods than overflow channels and so have relatively stable flows. Groundwater channels provide winter and summer refuge for juvenile fish, larval and adult amphibians, and a suite of invertebrates; spawning habitat for adult fish, some amphibians, and some invertebrates; and foraging habitat for many bird and mammal species.
>
> *Wall-based channels* can be groundwater fed but are often fed from springs or surface water from an adjacent terrace. They are usually higher in elevation relative to percolation-fed channels. Habitat projects might include providing fish access to them and enhancing habitat within the channels.
>
> *Floodplain ponds* are natural or constructed ponds in or above the floodplain such as abandoned gravel pits, mill ponds, ponds, and river oxbows. They might be supplied by groundwater or surface water from streams or springs and may or may not be connected to the river. Habitat projects might include providing fish access to them and enhancing habitat within the ponds. Though the origin and hydrology of floodplain ponds may be different than a wall-based channel, in this guideline they are described together.

Floodplain channel and pond features in the assessment reach are included in Table X. The types of sidechannels include relic channels where the river was once located, backwaters connected to the mainstem that are scoured during high flows, floodplain ponds, and flood flow channels. The channels vary in their degree of ground water influence.

Table X. Floodplain channel and pond features in the assessment reach.

Alignment Station	Channel/Floodplain Location	Type of Sidechannel	Estimated Length (ft)	Groundwater Influence
16+00	Left	Backwater	500	Unknown
28+00 to 49+00	Left	Overflow Relic Channel/Perc/Floodplain Pond	2,000	Based on topography to south
33+00	Right	Backwater	100	Unknown

4.2.4 Fish Habitat Conditions

In the study area, Reach 1 provides an intermediate level of fish habitat diversity. The sinuous C stream type provides juvenile rearing, adult resting, and spawning habitat. Juvenile rearing habitats include backwater channels, shallow channel margins in the lower third of meanders, and adjacent to point bars. Backwater channels typically connected with the mainstem channel in the lower third of meanders. Backwater channels were either connected with the baseflow channel or would be connected at elevated river stages. These areas provide ideal rearing habitat as well as resting habitat for all age classes when the river stage increases during high water. Shallow channel margins often supported sedges and rushes that provide additional cover for juvenile fish.

5.0 RESTORATION/CONSERVATION PRIORITIZATION PLAN

5.1 Introduction

In addition to evaluating existing stream corridor conditions in the project reach, another goal of the assessment was to propose restoration treatments for improving conditions for the Calapooia River fish community. Proposed restoration treatments are generally site-specific, although types of treatments are repeatedly recommended throughout the project area.

5.2 Scientific-basis for Recommended Treatments

Recommended treatments in the project area are aimed at increasing habitat diversity for the Calapooia fish community, stabilizing eroding banks to preserve landowner properties, and enhancing the riparian community for stream shading and habitat. Treatments include sidechannel, backwater, and floodplain pond enhancement; streambank modifications for bank protection and land preservation; and riparian buffer establishment and revegetation. The following sections provide the scientific-basis for the recommended treatment types.

5.2.1 Sidechannel, Backwater, and Floodplain Pond Enhancement

Sidechannels, backwater habitats, and floodplain ponds provide a range of habitats for favorable for juvenile fish rearing and adult fish holding. These habitats also support a range of wildlife species including birds and amphibians. These unique features are influenced by river hydraulics, sediment transport, vegetation conditions, large wood, and ground water-surface water interactions. Enhancing existing features, creating new features, or re-establishing these habitats in historical channel locations, offer a range of opportunities for increasing the frequency and quality of these habitats.

A variety of factors have likely reduced the number and/or capacity of sidechannels in the assessment reach. Activities including land reclamation for agriculture, log transport and splash-damming, channel straightening and dredging, dike construction, removal of large woody debris jams, urbanization, and the Brownsville Dam, led to channel simplification and loss of unique habitats.

Side channels often derive a major portion of their flow from either groundwater or seepage from the adjacent stream/river. The role of surface water in side channel habitats varies depending on mainstem and groundwater hydrology, channel topography, and physical features.

Additional information that would be necessary for designing sidechannel enhancements including the following items.

- High and low flow water surface profiles to determine appropriate sidechannel elevations. This information will require additional data collection and at-a-station hydraulic modeling.
- Existing ground surface profiles and cross-sections where the sidechannel enhancement will be completed to determine excavation volumes.
- Availability of large wood in the sidechannel area that can be relocated for habitat enhancement and grade control.
- Modeled hydraulics of the sidechannel to size bed sediment materials for grade control.

Understanding what fish species are using sidechannel and floodplain ponds in the respective areas would also be useful for anticipating fish response. Ponds that are currently isolated from the baseflow channel should be sampled to determine introduced fish species presence. Removing these species prior to connecting ponds with the mainstem via sidechannel enhancement would be preferable.

The desired sidechannel and floodplain pond enhancement outcome is one that maximizes the recruitment of adult and juvenile fish without trapping them. The enhanced sidechannels should also be self-sustaining. Fish that strategically use side channels may have an innate ability to sense groundwater sources. Peterson (1985) stated that the point where the egress channel joins the stream is the most critical aspect of project design. Nickelson et al. (1992) stressed that sidechannels remain open at all flow levels and recommended locating alcoves at springs and tributary junctions to maximize the potential for fish use.

If flow from a channel exits into a low-velocity area or eddy with habitat cover, the water is not rapidly diluted and fish have a better opportunity to find the spring-fed sidechannel than if the cooler sidechannel water is rapidly dispersed and diluted in rapid turbulent flow. The majority of the Calapooia River sidechannels will join the mainstem in locations where alcoves and backwaters are already present. These sites are typically well-vegetated, are characterized by lower water velocities, and are somewhat depositional. Woody debris is often also located at these sites, providing diverse habitats.

Sidechannel Ecological Benefits

Off-channel habitats such side channels and other permanently flooded area are important rearing areas for juvenile salmonids (Groot and Margolis 1991) and offer a wide variety of ecological benefits to other native fish species, amphibians, and wildlife.

Artificially constructed channels have been shown to support densities of juvenile salmonids equal to or greater than levels observed in natural sidechannels (Morley 2005). Morely (2005) also found that constructed sidechannels connected to shallow groundwater sources stayed cooler in the summer and warmer in the winter when compared to reference sidechannels and mainstem reaches. In the winter, even slightly lower water temperatures cause juvenile salmonids to become

Table X. Floodplain channel and pond features in the assessment reach.

Alignment Station	Channel/Floodplain Location	Type of Sidechannel	Estimated Length (ft)	Groundwater Influence
66+00	Right	Point Bar/Backwater	75	Hyporheic
70+00	Right	Overflow Relic across exiting meander	300	Unknown
77+00	Left	Backwater Floodplain Pond	250	Likely from natural floodplain pond
84+00 to 101+00	Left	Overflow Relic Channel/Floodplain Pond	950	Likely from natural floodplain pond
98+00 to 117+00	Right	Overflow Relic	700	Unknown
128+00 to 136+00	Right	Overflow Relic	800	Hyporheic via gravel bar
226+00 to 231+00	Right	Overflow Relic/Floodplain Pond	300	Likely from natural floodplain pond
235+00 to 252+00	Right	Overflow Relic/ Floodplain Pond	800	Likely from excavated floodplain pond
236+00 to 252+00	Right	Overflow Relic	2,000	Unknown
280+00 to 292+00	Left	Overflow Relic/Floodplain Pond (284+00)	1,200	Hyporheic via gravel bar and natural pond
289+00 to 296+00	Right	Overflow Relic/Floodplain Oxbow Pond	700	Hyporheic via gravel bar and natural pond
356+00 to 366+00	Left	Relic Channels	1,000	unknown

Reach 1 and Reach 3 in the assessment area included the greatest number and variety of sidechannels. The valley morphology in these two reaches permit greater floodplain development than the laterally constricted Reach 2 and Reach 4. In Reach 1 and 3, the river has developed a wider meander beltwidth. As the river has moved across the floodplain, it has created a mosaic of floodplain habitats. delineations show the greatest potential for side channel creation and enhancement projects. Conversely, Reach 2 in the area of Brownsville is modified to permit residential development. Reach 4 to Sodom ditch is topographically constrained and likely had few historical sidechannels.

Sidechannel Prioritization Considerations

Due to the large number of sidechannels in the project area, a prioritization system was developed to rank sidechannels for enhancement. Variables used to prioritize sidechannels for enhancement included the following conditions.

- Sidechannel length and proximity to mainstem.
- Probability of intercepting ground water (e.g. location of historical channel).
- Riparian canopy condition.
- Sidechannel proximity to floodplain pond.

Table X. Proposed LWD treatment locations, number, and associated habitat features.

Station	Location	Number of ELJ's	Associated Feature
14+00	Right	1	Backwater
23+00	Left	1	Existing barb
24+00	Right	3	Floodplain gravel bar
28+00	Left	2	Eroding bank
40+00	Right	3	Eroding bank
43+00	Right	1	Eroding bank
43+00	Left	2	Backwater
53+00	Left	2	Disturbed floodplain
62+00	Right	3	Floodplain gravel bar
66+00	Right	3	Eroding terrace
104+00	Left	1	Eroding bank
136+00	Right	2	Backwater
155+00	Left	3	Eroding bank
175+00	Left	3	Eroding bank
192+00 to 198+00	Left	Multiple	Rip-rapped bank
209+00 to 211+00	Right	Multiple	Failed bank stabilization debris
231+00	Right	1	Upstream of prior ELJ/barbs projects
238+00	Left	3	Backwater
239+00 to 241+00	Left	Multiple	Eroding terrace
252+00 to 256+00	Right	3	Habitat
258+00	Left	2	Backwater
259+00 to 261+00	Right	3	Habitat
269+00	Left	1	Backwater
300+00 to 302+00	Left	1	Backwater side channel
332+00 to 336+00		4	Pocket pool habitat in straightened channel
339+00	Left	2	Backwater side channel
366+00	Left	1	Backwater side channel
358+00 to 364+00		Multiple	Banks and backwater
373+00	Right	2	Eroding bank
393+00	Right	2	Backwater
398+00 to 400+00	Left	3	Existing barbs

more sluggish and thus more vulnerable to predation (Sandercock 1991). During the summer, warmer temperatures result in higher fish metabolic rates and a corresponding increase in food requirements (Welsh et al 2001). Sidechannels typically provide habitats influenced by both groundwater inputs and riparian vegetation. Unlike the Calapooia River mainstem which offers minimal shade (2004 Assessment), the proposed sidechannel locations are influenced by groundwater and also have moderate to dense multi-story riparian canopies. These two characteristics would be expected to result in warmer winter time water temperatures, and cooler summer water temperatures.

By locating sidechannels in areas of groundwater upwelling and providing appropriately sized gravels, constructed channels can also provide spawning habitat for *adult* salmonids (Cowan 1991). In addition, sidechannels are likely to offer adult fish with refugia from high flows. Off-channel refugia may be especially important for migratory species engaged in strenuous spawning migrations. Though coho have been the focus of many studies regarding the use of off-channel habitat, many other species of fish utilize sidechannels habitat at various lifestages (Lister and Finnigan 1997). Fish species inhabiting the Calapooia River that would be expected to benefit from sidechannel enhancement include the listed spring Chinook and winter steelhead, mountain whitefish, three-spined stickleback, Oregon chub, and cutthroat trout. Amphibians and pond turtles also stand to benefit from enhanced off-channel habitats.

5.2.2 Large Woody Debris

Large woody debris (LWD) can be used to disperse flow energy (Buffington and Montgomery 1999), stabilize channel banks and bed forms (Bilby 1984), increase aquatic habitat (Bryant and Sedell 1995), narrow a stream and reduce the width to depth ratio (Sedell and Froggatt 1984), cause localized deposition (Keller et al. 1985), form pools (Bilby and Ward 1989), and route flood water (Ellis 1999). Installation of large woody debris (LWD) in the assessment reach is intended to serve multiple purposes. First, engineered log jams (ELJs) are recommended for protecting stream banks. ELJs are placed to intercept high water flow vectors. The ELJs deflect the flow away from the streambank but also promote vertical channel scour. Scour pools typically form in from of the ELJ. Scoured sediments are typically transported a short distance and deposited as a tailout feature of the scoured pool. Depending on the site hydraulics, the deposited gravels may be used by spawning fish. On the Calapooia River, ELJs are recommended for outside streambanks that are experiencing accelerated erosion, to augment existing bank stabilization projects that exhibit streambank erosion, or to diversify aquatic habitats in morphologically-homogenous sections of the river.

Placement of large wood is also recommended for enhancing off-channel habitats. Unlike ELJs which typically involved at least ten logs and considerable rock for structure ballast, large wood for habitat enhancement typically requires less material. Since the large wood will be placed in off-channel habitats (e.g. sidechannels, alcoves, and floodplain ponds), the wood will be subjected to lower water velocities. To maintain structure stability, logs can be partially buried, braced between standing mature trees, or pinned together. Large wood with branches and rootwads provide the greatest range of microhabitats and also resist transport relative to limbed, cut logs.

Table X includes locations and characteristics of LWD prescribed for the Calapooia River. In addition to these locations, LWD would also be used to enhance excavated off-channel habitats.

5.2.3 Riparian Buffers and Site Revegetation

Table X. Proposed riparian buffer locations.

Station	Location	Recommended Treatment
147+00	Left	Increase buffer width. Revegetate.
157+00	Left	Increase buffer width. Revegetate
160+00	Right	Increase buffer width. Revegetate
166+00	Left	Increase buffer width. Revegetate
176+00	Right	Increase buffer width. Revegetate. Discontinue mowing.
222+00 to 226+00	Right	Increase buffer width. Revegetate. Monitor urban development.
270+00 to 274+00	Right	Increase buffer width. Revegetate

5.3 Site Specific Restoration Plans

5.4 Project Prioritization Plan

5.5 Summary

Most of the proposed ELJ projects addressing bank erosion will likely be accompanied by vegetated soil lift treatments (VSL). A single or double layer VSL would be constructed on top of the bench to facilitate vegetation establishment. VSLs are a revegetation and bank construction technique that combines layers of dormant willow cuttings with fabric-wrapped soil to revegetate and stabilize stream banks and slopes. Soil is wrapped within two layers of biodegradable coconut fiber (coir) fabric, to hold the soil in place while vegetation becomes established in the relatively high stress land/water interface. Soil lifts, combined with a bench, will result in near bank areas where native woody vegetation can become established. The face of the bottom soil lift will be reinforced with high density coir logs or other suitable material to help maintain the lift shape, keep fine soil particles from filtering out through the lift face, and maintain surface tension. The uppermost soil lift should be filled with soil (sandy loam or topsoil) capped with salvaged sod or seeded with the seed mix developed for the site. Soil lifts will be tied into the ELJs. Willow and cottonwood cuttings will also be planted on the bench.

Large Wood Ecological Benefits

Observations from intact low-gradient rivers suggest the on-going loss of wood substantially reduces biocomplexity (Gurnell et al. 2005) and alters key biophysical patterns in developed rivers. When present, logs enhance instream complexity and promote floodplain inundation (Kellerhals et al. 1976; Brooks et al. 2003). Large logs are central to organic matter retention (Bilby and Likens 1980; Bilby 1981), to pool formation (Abbe and Montgomery 1996; Beechie and Sibley 1997), and to nutrient uptake (Aumen et al. 1990; Valett et al. 2002). Remnant logs provide habitat for a variety of terrestrial organisms (Bull 2002; Steel et al. 2003) and facilitate conifer establishment (Van Pelt et al. 2006). Most logs reside in floodplain river valleys for decades, though some fraction lasts for centuries or more (Nanson et al. 1995; Montgomery and Abbe 2006). Those remaining stable over long periods may represent a sizeable carbon reservoir (Guyette et al. 2002) and aid in replenishing supplies of new large logs by protecting developing forests from erosion long enough for trees to grow large (Montgomery and Abbe 2006). In the absence of large wood, few structures in low-gradient rivers are suitable ecological surrogates for these functions.

Studies have documented the importance of large wood within the stream channel to slow bedload movement, deposit and sort gravel, scour pools, and increase nutrients through salmon carcass retention time (Swanson et al. 1976, Ralph et al. 1994). Pools with large and complex accumulations of wood often show higher densities of rearing juvenile salmonids, particularly in winter, when storms routinely cause flooding. More recent studies have also shown the increase in percentage of surface area of pool habitat, pool depth, and an *increase in winter sidechannel habitat* following the placement of large wood in restoration activities (Johnson 2005). Results from Johnson (2005) indicate a higher smolt survival rate for coho, steelhead, and sea run cutthroat trout following large wood treatments in two streams.