CALAPOOIA RIVER GEOMORPHIC ASSESSMENT
SODOM DAM BIFURCATION TO BUTTE CREEK CONFLUENCE

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EXECUTIVE SUMMARY

As a main tributary to the Willamette River in western Oregon, the Calapooia River drains the Cascade Mountain Range. Flowing in a westerly direction from its headwaters, the Calapooia River drains forested and agricultural land before joining the Willamette River at Albany. Chinook, steelhead, cutthroat, and Oregon chub are some of the native fish species that continue to inhabit the Calapooia River. Timber production, splash damming for log transport, irrigation systems, agriculture, and residential development have affected the Calapooia River and its fisheries. Limiting factors impacting the native fish community include fish passage barriers, simplified habitat, summertime water temperatures, and loss of riparian forests and associated large wood that once created dynamic habitat.

The Calapooia Watershed Council retained River Design Group, Inc. (RDG) to complete a geomorphic assessment in an effort to further develop fish passage alternatives and scenarios for alteration of the Sodom Dam. For the geomorphic assessment, RDG completed a reach reconnaissance, field survey, and remote sensing tasks to evaluate historical and existing conditions from the Calapooia River-Sodom Ditch bifurcation upstream from Sodom Dam, downstream to the Calapooia River-Butte Creek confluence. At-a-section hydraulic models were developed to determine channel capacity and hydraulic conditions through the approximately 10.8 mile project reach.

Preliminary analyses highlight the dynamic nature of the Calapooia River and the role of diversion dams on channel morphology in the assessment reach. A review of historical aerial photos points to significant changes in the channel planform that have occurred since the 1930s. Field data suggest the role of the diversion dams in controlling upstream channel gradient and arresting downstream channel incision.

Dam alterations or removal, along with fish passage alternatives, will be developed during subsequent phases of this project.

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GLOSSARY

Active Floodplain: Lowlands bordering a river, which are subject to flooding on a periodic basis. Floodplains are composed of sediments carried by rivers (alluvium) and deposited on land during flooding. The active area is characterized by recently deposited river-borne debris, limited terrestrial vegetation, and recent scarring of trees by material transported by floodwaters.

Aggradation: The geologic or fluvial process by which streambeds, floodplains and the bottoms of other water bodies are raised in elevation by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

Alluvial: Deposited by running water.

Anadromous: Fish that breed in freshwater but live their adult life in the sea. On the Pacific coast, anadromous fish include all the Pacific salmon, steelhead trout, some cutthroat trout and Dolly Varden char, lampreys and eulachons.

Avulsion: An abrupt change in the course of a stream whereby the stream leaves its old channel for a new one.

Bankfull (Stage): Water surface elevation at which a stream first overflows its natural banks, spilling water onto the floodplain.

Base Flow: Streamflow coming from sustained subsurface sources, not directly from surface runoff.

Bedload: Sediment particles transported on or near the streambed by rolling and bouncing.

Belt Width: Total width across which the river meanders.

Bifurcate: The division of a stream channel into two branches or a fork in the stream channel.

Braided Stream: Stream that forms a network of branching and recombining channels separated by islands or channel bars.

Channelization: Straightening and (or) deepening a pre-existing channel, or constructing a new channel, for the purpose of runoff control or navigation.

Degradation: Removal of materials from one place to another via erosion, causing lowering of the elevation of streambeds and floodplains over time.

Floodplain: A level, low-lying area adjacent to streams that is periodically flooded by stream water. It includes lands at the same elevation as areas with evidence of moving water, such as active or inactive flood channels, recent fluvial soils, sediment on the ground surface or in tree bark, rafted debris, and tree scarring.

Groundwater: Subsurface water in the zone of saturation below the level of the water table, where the hydrostatic pressure is equal to or greater than the atmospheric pressure.

Hydric: Sites where water is removed so slowly that the water table is at or above the soil surface all year; gleyed mineral or organic soils are present.

Hyporheic Zone: Zone beneath and adjacent to streams where water and dissolved chemicals move easily between surface and groundwater.

Large Woody Debris: Coarse woody material (conventionally greater than 10 cm in diameter and 1 m long), such as twigs, branches, logs, trees, and roots, that falls into a stream.

Manning's n-value: Empirical coefficient for computing stream bottom roughness, or the irregularity of streambed materials as they contribute to resistance to flow, which is often used to determine water velocity in stream discharge calculations.

Meander: A sinuous channel form in flatter river grades formed by the erosion on one side of the channel (pools) and deposition on the other side (point bars).

Meander Length: Distance in the general course of the meanders between corresponding points of successive meanders of the same phase. Twice the distance between successive points of inflection of the meander wave.

Off-channel: Bodies of water adjacent to the main channel that have surface water connections to the main river channel at summer discharge levels.

Planform: The bird's eye view of a stream or river's pattern and location on the landscape.

Project Area: The 10.3 river mile project area extending from the Calapooia River-Sodom Ditch bifurcation, downstream to the Calapooia River-Butte Creek confluence.

Riffle: A shallow section of a stream or river characterized by rapid current and a surface broken by completely or partially submerged obstructions such as gravel or boulders.

Riparian (Area): An area of land adjacent to a stream, river, lake or wetland that contains vegetation that, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas. The riparian area is influenced by and influences the adjacent body of water.

Riprap: A layer of large, durable material such as coarse rock used to protect exposed surfaces and slopes susceptible to erosion such as fills and streambanks

Salmonid: Refers to a member of the fish family *Salmonidae*, including the salmons, trouts, chars, whitefishes and grayling.

Shear Stress: Stress caused by forces operating parallel to one another but in opposite directions.

Sinuous: Characterized by a serpentine or winding form, typically referring to stream channels.

Substrate: The basic surface on which material adheres, typically mineral and (or) organic material that forms the bed of a stream.

Thalweg: Line of deepest water in a stream channel as seen from above. Normally associated with the zone of greatest velocity in the stream. If there is no stream, it is the line of lowest points of a valley.

Watershed: Also referred to as a drainage basin or catchment area. Watersheds are the natural landscape units from which hierarchical drainage networks are formed. Watershed boundaries typically are the height of land dividing two areas that are drained by different river systems.

1 INTRODUCTION

The Calapooia Watershed Council (CWC) retained River Design Group, Inc. (RDG) to complete the *Sodom Dam Removal Feasibility and Fish Passage Design Report*. The project scope of work included reviewing existing information, completing a field reconnaissance and site surveys, executing remote sensing of time series air photos, and characterizing existing hydraulic conditions for select river reaches. The project area includes the Calapooia River from the Calapooia River-Sodom Ditch bifurcation, downstream to the Calapooia River-Butte Creek confluence, a distance of approximately 10.8 miles.

The purpose of the project is to evaluate historical and existing river corridor conditions. RDG and CWC developed the following project objectives for the project.

1) Evaluate historical and existing river corridor conditions in the 10.8 mile project reach.
2) Assess the effects of infrastructure, river management and land use on fish passage, river stability, flood stage, and flood flow conveyance.
3) Evaluate channel succession trends, over time, and future potential geomorphic changes to the river and floodplain system.
4) Coordinate with project stakeholders to address landowner and agency personnel concerns.

2 METHODS

RDG completed remote sensing, field assessment, and hydraulic modeling efforts for the project. The following sections outline the methods employed for each effort.

2.1. Remote Sensing

RDG completed several remote sensing tasks for the project. Remote sensing tasks included the following items.

- Historical aerial photo analysis
- Soils, geology, and vegetation mapping and spatial analysis
- Base map production to support field data collection efforts and river reach assessments

ArcGIS programs were used to complete remote sensing tasks. Programs included ArcGIS Version 9.1 (ESRI 2005a) and ArcGIS extensions, Spatial Analyst (ESRI 2005b) and 3D Analyst (ESRI 2005c). Spatial data were acquired from multiple state and federal agency sources.

2.1.1. Historical Aerial Photo Analysis

The historical channel plan form analysis was completed to evaluate changes in the Calapooia River project area between 1936 and 2005. Historical aerial photographs and maps were acquired for the analysis. Channel plan form measurements were completed using ArcGIS. Remote measurements were verified in the field. Other observations pertaining to vegetation community types, infrastructure affecting river and floodplain processes, and land uses were made using aerial photo interpretation with ground verification. The purpose of the historical aerial photo analysis was to evaluate river corridor changes over time, identify potential cause of channel change, and to predict the future morphological adjustment of the Calapooia River and floodplain ecosystem.

Aerial Photo Acquisition

Time series aerial photographs were acquired as scanned .jpeg files from the U.S. Army Corps of Engineers. Acquired air photo series were from 1936, 1956, 1967, and 1991. The aerial photos were registered to the 2005 National Agriculture Imagery Program (NAIP) photos. The 2005 NAIP images were also used for the analysis. The 1853 General Land Office (GLO) survey maps were also acquired and evaluated. ArcGIS was used to digitize the Calapooia River channel and the Sodom Ditch for each photo series.

The following information provides an overview of the historical air photo and map sources.

1853 GLO Maps

The 1853 GLO maps were acquired from the University of Oregon on-line library (http://libweb.uoregon.edu/map/GIS/Data/Oregon/GLO/index.htm). GLO maps covering the extent of the project area (bifurcation to the confluence of the Calapooia River and Butte Creek) contained minimal features suitable for Ground Control Points (GCPs), with the exception of Public Land Survey System (PLSS) lines. A shapefile of PLSS lines from the Linn County GIS Database, accurate to 1:100,000 scale, was used for georectification. Thirteen GCPs based on the intersections of section lines resulted in a Root Mean Squared Error (RMSE) of 16.9 ft for the GLO map covering Township 13 South, Range 3 West, and 19.7 ft for the GLO map covering Township 12 South, Range 3 West.

When the two GLO maps were compared, the Calapooia River channel was found to be offset by 1,073 ft. In addition, the channel alignments on both maps were inconsistent with historical vegetation distributions, elevation gradients and other environmental features. Due to these inconsistencies and the lack of published accuracy metadata, the 1853 data set was eliminated from the analysis.

Historical Air Photos

Aerial photos obtained from the Army Corps of Engineers were rectified to Digital Orthoquad aerial photos from the 2005 National Agricultural Imagery Program (NAIP). National Agricultural Imagery Program (NAIP) digital georectified image obtained from the Oregon State University Imagery Portal (http://imagery.oregonexplorer.info/Plugin.htm). In summary, eleven photos from 1936, seven photos from 1956, thirteen photos from 1967 and four photos from 1991 were rectified, using a minimum of six GCPs and a maximum of 20 ft RMSE.

Channel Digitization and Plan Form Analysis

Using the ArcView 9.2 GIS platform (ESRI 2007), channels were digitized for all years in the study. A maximum scale of 1:3,000 was used for the digitization process, and a 2,000 ft buffer at the edge of each aerial photo prevented the inclusion of distorted edge effects (from off-nadir look angles).

Following digitization of the Calapooia River, meanders for each year were identified, and lines were digitized between each meander's point of maximum curvature (Figure 1-1). Beltwidth extents and curvature radii were also digitized at each of these points.

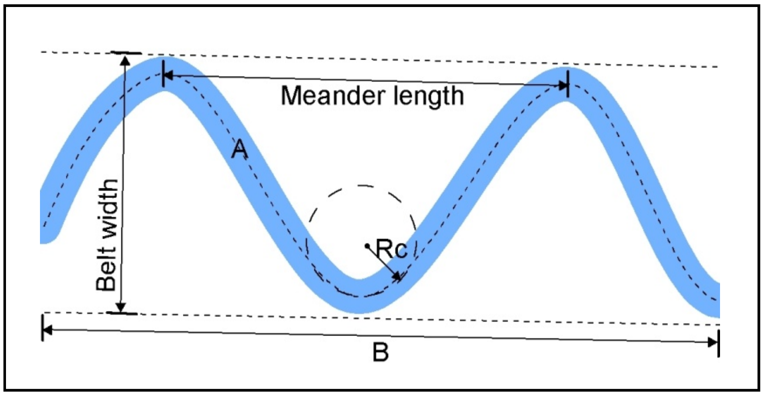

Figure 1-1. Illustration of plan form metrics (Adapted from Rosgen 1996). Rc denotes the radius of curvature. Meander length is the distance between two bends in the river. Belt width is the width of the river corridor. Sinuosity is the channel length (dashed line A) divided by the straight line length of the valley bottom (line B).

The radius of curvature, which can be used to evaluate channel resistance to erosion and bend or meander migration rates, was defined as the length of the radius of the meander arc. Meander belt width or amplitude measurements were made to describe the lateral containment of the river and floodplain. Finally, sinuosity, which describes how a river has adjusted its slope to the valley, was computed as the channel length in river miles divided by the straight line length of the valley bottom. The meander length, belt width, radius of curvature, and sinuosity were all statistically analyzed for the mean, minimum, maximum and standard deviation values.

2.1.2. Soils, Geology, and Vegetation Map Production

Soils, geology and vegetation GIS layers were acquired and superimposed on the 2005 NAIP imagery to investigate geographic patterns relative to the river corridor.

Soils Data

Soils data acquired for the project area included:

- Soil order and suborder
- Soil bulk density
- Soil C horizon clay content
- Soil C horizon organic matter content
- Soil map unit information

Soil map unit data were presented over the 2005 NAIP imagery for comparing soil units adjacent to the Calapooia River and Sodom Ditch.

Geologic Data

Geologic data were acquired from the U.S. Geological Survey and the State of Oregon (Beaulier 1974). The geologic data layer was presented over the 2005 NAIP air photo graph. The data layer was truncated to the project area. Explanations for the geologic formations in the project area were presented on the map.

Vegetation Data

Two images, one from July 7, 1987 (Landsat TM) and one from July 29, 2001 (Landsat ETM+) were acquired from the Global Land Cover Facility. The 2001 image was radiometrically corrected using Pseudo-Invariate Features to account for sensor differences, sensor degradation, atmospheric variability, and sun angle. Both images were clipped to the riparian vegetation boundary from the 1936 air photos. The Normalized Difference Vegetation Index (NDVI), which has a strong correlation to vegetation biomass, was calculated for the 1987 and 2001 images. The NDVI calculated for the 1987 image was compared to the NDVI calculated for the 2001 image. The change in the NDVI between the two years represents the relative biomass percentage change from 1987 to 2001. Due to the scarcity of data points, inter-annual variability in temperature, precipitation, and other factors, the change in the NDVI should be judged in relative rather than absolute terms. A change of 0 – 0.1 may represent a decline in vegetation, whereas a change of 0.9 – 1 may only represent a slight increase in vegetative growth. Adding addition Landsat imagery to the database would allow additional investigations of vegetation changes over time.

Riparian corridor extent was also compared between the 1936 and 2005 air photo imagery. Comparisons were made for several locations in the project area.

2.1.3. Base Map Production

Base maps were produced for the project area to assist in the field reconnaissance as well as to provide a background for displaying GIS data. Base maps include the 2005 NAIP imagery. For the field reconnaissance, a centerline alignment and stationing were added to the maps. Landmarks including infrastructure, roads, and other geographical were plotted on the base maps.

2.1.4. Field Assessment Data Mapping

Channel cross-section and profile data, infrastructure data, and other data points were plotted on the base maps to display data collection locations by river reach.

2.2. Field Data Collection and Reconnaissance

Field data collection methods included a reconnaissance-level river walk-through, infrastructure surveys, and characterization of channel-floodplain morphology and hydraulics. The field surveys characterized typical channel conditions in each of the four reaches that were established. One reach could not be surveyed due to excessive flow depths that precluded wading. Project reaches were delineated according to the presence of infrastructure (e.g. Shear Dam), changes in streamflow related to diversions and returns, and Rosgen stream types (Rosgen 1996).

RDG completed a river reconnaissance on the Calapooia River from the Calapooia River-Sodom Ditch bifurcation downstream to the Calapooia River-Butte Creek confluence. The project reach totals approximately 10.8 river miles. The four delineated reaches include the following.

- Reach 1: Calapooia River-Sodom Ditch bifurcation to the Interstate-5 bridge
- Reach 2: The Interstate-5 Bridge to Shear Dam
- Reach 3: Shear Dam to the Thompson's Mills spillway return
- Reach 4: Thompson's Mills spillway return to Butte Creek

The reconnaissance began at the Calapooia River-Sodom Ditch bifurcation and proceeded in a downstream direction on the Calapooia River to the Butte Creek confluence. This effort was complementary to previous work completed on Sodom Ditch in 2006 (Inter-fluve 2007). Tasks completed during the reconnaissance included the following.

- Confirmation of the reach break delineation based on aerial photograph interpretation.
- Evaluation of existing impaired and reference reach conditions.
- Observations on channel, vegetation, land use, and infrastructure conditions.
- Selection of representative sties for channel surveys.
- Photographic documentation of river corridor conditions.

Ground photographs and field notes are compiled in *Appendix A – Sodom Dam Photo Library*.

2.2.1. Channel Surveys

A RTK GPS was used to carry survey control into the project reach from pre-existing survey control in the vicinity of Sodom Dam. Channel surveys were completed with a total station. Survey data collection followed U.S. Forest Service (USFS) procedures (Harrelson et al. 1994) and included channel cross-sections and profiles. Survey data included cross-sections, longitudinal channel profiles, discharge measurements, pebble counts, and ground photos. Data were collected to characterize terrace, floodplain, bankfull, water surface, and thalweg features. Additional features that were surveyed to characterize river-influencing infrastructure included diversion dams, roads, and bridges. 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 processed using AutoCAD Civil 3D (Autodesk 2007).

A velocity meter was used to measure the average velocity at each surveyed cross-section. The channel area and average velocity were used to estimate the discharge at the time of each cross-section survey.

2.3. Hydraulic Modeling

Hydraulic modeling was completed to evaluate channel hydraulics in the four reaches. Models were developed to evaluate hydraulic conditions at the time of the survey (observed water surface elevations) and for full channel capacity to determine the frequency at which flows overtop the channel banks and inundate the floodplain. A modified flood frequency based on the division of river discharge at the bifurcation point was used for determining the 2-year discharge in the Calapooia River. A description of the modified flood frequency is provided in Section 3.2.

Models for Reaches 1 through 3 included two cross-sections and a channel profile. Because only one cross-section was surveyed in Reach 4, an at-a-section hydraulic model was completed for Reach 4. HEC-RAS v4 (USACE 2008) was used for the modeling effort. Data used in the models included the respective channel cross-sections, the measured water velocities, and water surface, bankfull, and floodplain slopes.

3 CALAPOOIA RIVER WATERSHED OVERVIEW

The following sections are largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004). This information is provided as a summary of historical and existing conditions that are important to consider when evaluating both the current state of the river corridor, the restoration objectives, and the potential to re-establish ecological processes. The assessment excerpts are primarily related to the Middle Calapooia River, the focus area of this assessment.

3.1. Historical Landscapes

The following section is largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004).

By the 1950s, the landscape features of the Calapooia River watershed had changed dramatically relative to pre-1850 conditions. Lands that were historically grass prairies, oak woodlands, wetlands, and riparian forests had been converted to farmlands, and, to a lesser extent, other land uses. The end of the Kalapuyan (indigenous tribe that inhabited the watershed prior to the arrival of Euro-American settlers) practice of using fire to control vegetation resulted in conversion of areas that were once grasslands and open oak woodlands to conifer forests. Stream habitat, especially along the Calapooia River, had been modified through a number of practices, including log drives down the river, removal of large wood from the channels, loss of riparian habitat, and bank stabilization. A number of dams within the Calapooia River presented obstacles to fish migration. Large scale bank stabilization projects took place following the 1962 floods to reduce property loss.

Land use activities including agriculture, logging, and residential development have led to the simplification of the once dynamic Calapooia River corridor.

3.2. Hydrology

Flows in the Calapooia River vary greatly throughout the year due to seasonal precipitation and summer use of water. The average monthly January flow in Albany is 55 times the average August monthly flow. Nearly 90% of the runoff occurs during the six wettest months (November through April). The magnitude of annual runoff also varies. Rain-on-snow flood events have been responsible for the largest floods of record. These events typically occur between December and February when warm storms rain on the snowpack.

TetraTech (2008) performed a hydraulic analysis for the Sodom Ditch Dam Conversion project in May, 2008. One of two primary goals of the hydraulic analysis and modeling effort was to develop an understanding of the hydraulic processes involved in the division of flow between Sodom Ditch and the Calapooia River downstream of the bifurcation. Specific objectives included defining the actual division of flows at the bifurcation and to produce a base hydraulic model that can be modified during subsequent design phases to simulate the response of the river system to various options and alternatives.

The flow analysis was performed based on the Guidelines for Determining Flood Flow Frequency, Bulletin #17B (USGS 1982). Data were obtained from two gage stations. Gage station 1417200 is located upstream of the study area near the town of Holley, and has a period of record from 1935 to 1990. The second station, 14173500, is located downstream of the study area near Albany. The station has a period of record from 1940 to 1981.

TetraTech conducted flood frequency analyses from the annual instantaneous peak flows for both gage stations. Flow rates were proportionally adjusted for the point entering the study area. Table 3-1 presents a summary of the calculated instantaneous peak flows at the gage stations and at the bifurcation point at the upstream end of the project area.

Table 3-1. Results of the log-Pearson Type III probability distribution for Gage 14173500, Gage 1417200, and the bifurcation point at the upstream end of the project area (TetraTech 2008).

	Drainage	Recurrence Interval (yrs) and Instantaneous Peak Flow (cfs)							
Location	Area	1.01	2	5	10	25	50	100	500
Gage 14173500 (Downstream)	372.3	2,921	12,104	19,727	25,300	32,954	38,967	45,219	51,798
Gage 14172000 (Upstream)	101.2	1,904	5,488	7,915	9,552	11,644	13,214	14,787	16,387
Bifurcation	164.0	2,140	7,021	10,652	13,207	16,582	19,181	21,837	24,591

To calculate flows in both Sodom Ditch and the Calapooia River downstream of the bifurcation, a HEC-RAS model was developed to perform one-dimensional hydraulic modeling. Input parameters included the stream alignment created by Ron Bush Surveying and Engineering, channel cross-sections derived from the topographic survey, roughness coefficients based on a variety of methods, calculated flow rates, and boundary conditions including average channel slope. Based on these input parameters and the established channel geometry, the percentage of flow entering Sodom Ditch and the Calapooia River downstream of the bifurcation was determined. Results are summarized in Table 3-2 including total flow and percent of total flow entering Sodom Ditch and the Calapooia River for select recurrence intervals. Results are based on modeled flow division for the existing dam without flashboards.

Table 3-2. Modeled flow division for the Calapooia River and Sodom Ditch at the bifurcation point based on existing dam without flashboards (TetraTech 2008).

		Calapooia River		Sodom Ditch	
Total Flow Entering (cfs)	Recurrence Interval (yrs)	Flow Rate (cfs)	Percent of Total	Flow Rate (cfs)	Percent of Total
25	<1	7.9	31.5	17.1	68.5
50	<1	12.8	25.5	37.3	74.5
100	<1	22.0	22.0	78.0	78.0
250	<1	53.7	21.5	196.3	78.5
500	<1	109.7	21.9	390.3	78.1
750	<1	167.0	22.3	583.0	17.7
1,000	<1	222.8	22.3	771.2	77.1
1,500	<1	331.6	22.1	1,158.4	77.2
2,140	1	457.7	21.4	1,644.3	77.8
7,020	2	1,576.0	22.5	5,444.0	77.6
10,650	5	2,666.4	25.0	7,983.6	75.0

Table 3-2. Modeled flow division for the Calapooia River and Sodom Ditch at the bifurcation point based on existing dam without flashboards (TetraTech 2008).

Total Flow Entering (cfs)	Recurrence Interval (yrs)	Calapooia River Flow Rate (cfs)	Calapooia River Percent of Total	Sodom Ditch Flow Rate (cfs)	Sodom Ditch Percent of Total
13,210	10	3,450.7	26.1	9,759.3	73.9
16,580	25	4,455.2	26.9	12,124.8	73.1
19,180	50	5,227.0	27.3	13,953.0	72.7
21,840	100	6,004.6	27.5	15,835.4	72.5
24,590	200	6,811.3	27.7	17,778.7	72.3

TetraTech concluded that the flow split to Sodom Ditch was higher than previously assumed, ranging from 68 to 77 percent (TetraTech 2008). This condition was partially attributed to sediment aggradation and large wood accumulation in the Calapooia River immediately downstream of the bifurcation point. As flows at the bifurcation point recede, the percent of total flow entering the Calapooia River decreases and becomes largely dependent on the elevation of the channel bed and the effects of sediment deposition just downstream of the bifurcation.

In summary, the following conclusions regarding the split flow conditions were determined from the hydraulic analysis performed by TetraTech.

- The division of flow to Sodom Ditch from the bifurcation is significantly larger at higher flows, with a percentage in the range of 68 to 77 percent conveying into Sodom Ditch.
- Sediment deposition, large wood accumulation, and natural river processes result in highly dynamic hydraulic conditions at the bifurcation.

3.3. Vegetation

The following section is largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004).

The Calapooia River supports a varied riparian vegetation community. In more extensive floodplain areas, hardwood species consist of Oregon ash, black cottonwood, bigleaf maple, and red alder. These trees usually occur in combination. Younger hardwood stands are prevalent in the Middle Calapooia River, but are relatively scarce in other reaches of the Calapooia River. The Middle Calapooia River also has a high percentage of area in gravel bars. Younger hardwoods, usually found situated between a gravel bar and the older hardwood stands, are probably a result of tree establishment in areas cleared of vegetation during a major flood.

Notes and maps from the original land surveys conducted in the 1850s indicate that the Calapooia River was bordered by a continuous corridor of trees. Because of repeated burning of the valley floor by Native Americans during the previous centuries, vegetation beyond this corridor of trees was mostly native prairie or oak savanna. An examination of natural and human features that currently occupy land within this historical corridor of trees indicates that the combined percentage of trees and water features is only about 50% of what it was in the 1850s. About one-half of the land along the Calapooia River that supported trees in the 1850s has since been converted to grass seed fields and other development. Remaining patches of older trees are mostly in low-lying areas that are too wet for farming (Figure 3-1). Older stands of trees are most extensive downstream of Brownsville where the river meanders widely over a relatively flat floodplain. In this vicinity, natural ponds are abundant, a result of the river abandoning its old channel and forming a new path. Most of the ponds are bordered by older hardwood stands and few have been altered by farming or development.

Figure 3-1. Examples of riparian conditions in Reach 1 (left) and Reach 2 (right) of the project reach. Native and invasive species characterize the riparian community through the project reaches. Residential and agricultural developments have replaced native vegetation assemblages.

3.4. Fisheries and Habitat

The following sections are largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004).

3.4.1. Fish Community

The Calapooia River fish community includes both native and introduced fish species. Native salmonids include winter steelhead, spring Chinook salmon, and mountain whitefish. Non-salmonid fish present in the watershed include Pacific lamprey, a variety of minnow and sculpin species, the largescale sucker, and other fish. There is a greater abundance of non-salmonid fish in the lower watershed, but some species, such as shiners and sculpin species are found throughout the watershed. There is also a variety of non-native fish in the watershed. These fish have been "introduced" (either accidentally or intentionally) to the Willamette River and tributary streams. Most of the documented use by non-native fish is in the lower watershed where warmer water temperatures and altered habitat have provided ideal conditions for many of these fish. Fish species inhabiting the Calapooia River watershed are included in Table 3-2.

Table 3-3. Native salmonids, native non-salmonids, and introduced fish species in the Calapooia River.

Fish Species	Notes
Native Salmonid Species	
Winter steelhead, *Oncorhynchus mykiss* Spring Chinook salmon, *Oncorhynchus tshawytscha* Cutthroat trout, *Oncorhynchus clarki clark* Mountain whitefish, *Prosopium williamsoni*	Willamette spring chinook and winter steelhead (both anadromous species) were listed as threatened under the federal Endangered Species Act (ESA) in 1999. Factors contributing to their decline include habitat loss, fish passage barriers, altered flow regimes, water quality, and the negative impacts of hatchery fish.
Native Non-salmonid Species	
Lamprey Pacific lamprey, *Lampetra tridentata* Western brook lamprey, *Lampetra richardsoni* Other species	Pacific lamprey are anadromous (adults reside in the ocean and return to rivers and streams to spawn) and brook lamprey are resident species. Pacific lamprey was listed as an Oregon state sensitive species in 1993 due to a serious decline in abundance.
Minnows Speckled dace, *Rhinichthys osculus* Longnose dace, *Rhinichthys cataractae* Nothern pikeminnow, *Ptycheilus oregonensis* Redside shiner, *Richardsonius balteatus* Chiselmouth, *Acrocheilus alutaceus* Peamouth, *Mylocheilus caurinus* Oregon chub, *Oregonichys crameri*	Dace occur throughout the watershed, primarily in the Calapooia River and the lower portions of tributaries. *Oregon chub* is a small minnow native to the Willamette River basin. Oregon chub were listed as endangered under the Federal ESA. Chub prefer low gradient tributaries and off-channel habitats such as side-channels and sloughs. Their decline has been attributed to loss of habitats, altered flow regimes, and predation.
Suckers Largescale sucker, *Catostomus macrocheilus*	Most suckers occur in the lower watershed, primarily in the Calapooia River.
Sculpins Mottled sculpin, *Cottus baurdi* Paiute sculpin, *Cottus beldingi* Prickley sculpin, *Cottus asper* Shorthead sculpin, *Cottus confusus* Reticulate sculpin, *Cottus perplexus* Torrent sculpin, *Cottus rhotheus*	Sculpins occupy streams throughout the watershed, with the greatest abundance in the upper Calapooia River and tributaries.
Sticklebacks Three-spine stickleback, *Gastrosteus aculeatus*	
Troutperch Sand roller, *Percopsis transmontana*	
Non-Native Species (all non-salmonid)	
Largemouth bass, *Micropterus salmoides* Smallmouth bass, *Micropterus dolomieui* Yellow bullhead, *Ameiurus natalis* Bluegill, *Lepomis macrochirus* Pumpkinseed, *Lepomis gibbosus* Crappie (black), *Pomoxis nigromaculatus* Brown bullhead, *Ameiurus melas* Western mosquito fish, *Gambusia affinis*	Most of these species occur in the lower watershed in the Calapooia River and permanent and seasonal tributary streams.

Table 3-3. Native salmonids, native non-salmonids, and introduced fish species in the Calapooia River.

Fish Species	Notes
Goldfish, *Carassius auratus*	

Anadromous fish spend a portion of their lives residing in the ocean and return to the watershed for spawning and juvenile rearing. There is concern over decreased populations of resident and anadromous fish that currently or historically resided in the Calapooia River watershed. Three anadromous fish species that reside in the Calapooia River watershed are: spring Chinook salmon, winter steelhead, and Pacific lamprey. Because anadromous fish have very complex life cycles, including migrating through the river and stream network as adults on their way to spawning areas and as juveniles moving downstream to the ocean, they are very vulnerable to predation and human-related issues such as passage barriers, fishing pressures, and changes in habitat.

Upper Willamette River spring Chinook salmon and winter steelhead are listed as *threatened* under the Federal Endangered Species Act. Pacific lamprey is listed as an Oregon state sensitive species. In addition to these anadromous fish, there are reduced populations of Oregon chub, a resident fish native to the Willamette River basin. Historically, chub used side channels and other backwater areas in the lower Calapooia River watershed (Figure 3-3). There are no current reports of populations inhabiting the Calapooia River. Oregon chub are also listed as endangered under the Federal Endangered Species Act.

Figure 3-3. An example of a floodplain channel that is inundated over a range of mainstem stages. These habitats provide off-channel habitat for fish and amphibians.

All of the seasonal streams examined by Oregon State University (OSU) in the Calapooia River watershed had highly variable stream flows that fluctuate with rainstorms. In the OSU study, cutthroat trout were the most common salmonids observed in seasonal streams, with some observations listing rainbow trout (probably they were juvenile steelhead) and juvenile spring Chinook salmon. Young spring Chinook salmon were present at three sites in January and February. These small, seasonal streams provide favorable habitat during winter high flows. During this period juvenile spring Chinook and winter steelhead, and adult trout escape from high velocity flows in the river by moving into these seasonal streams where there is slow water. Fish passage is an important issue in streams that are used seasonally by fish.

The greatest diversity of fish species is found in the lower Calapooia River Watershed. In this portion of the watershed most of the fish present in the entire Calapooia River Watershed are found at various times of the year. The most abundant fish species are the non-salmonids, both native and non-native. Fish such as three-spine sticklebacks, redside shiners, and suckers are more numerous than trout or salmon. In the upper watershed, this pattern is reversed, with salmonids the most abundant species and non-salmonids a minor component. While the lower river has fewer salmonids, it is an essential area for salmon, trout, and other species during part of their life cycle. The lower river is important as a migration corridor for anadromous winter steelhead, spring chinook salmon, and Pacific lamprey. Winter steelhead and spring Chinook salmon must pass through the river in lower and middle portions of the watershed on their way to spawning grounds in the upper watershed. In addition, the tributary streams provide important seasonal habitat during the winter and spring for juvenile salmonid species, including spring Chinook salmon and winter steelhead.

The middle watershed has a greater abundance of salmonid species and very few non-native fish above Brownsville (this observation was likely related to the former operation of the dam, the dam has been removed). The river channel through this portion of the watershed continues to be an important migration corridor for adult and juvenile winter steelhead, spring Chinook salmon, and Pacific lamprey. Juvenile spring Chinook and winter steelhead, for example, use the river and probably use the lower portions of tributaries such as Brush Creek for rearing, particularly during high flow events in the winter and early spring (Gary Galovich, ODFW, personal communication, 2003). There have been no observations of winter steelhead spawning in the tributary streams in this portion of the watershed. Many of the streams in the middle Calapooia River watershed have suitable winter steelhead spawning and rearing habitat, so it is possible that there may be a small population of winter steelhead using some of the tributaries (Gary Galovich, ODFW, personal communication, 2003). Cutthroat trout also use the river and tributary streams. In addition to the cutthroat trout that reside year round in small streams (resident), there are cutthroat (a *fluvial* population) that reside in this portion of the river that move up the river and into tributary streams for spawning.

3.4.2. Fish Passage Barriers

Fish passage barriers on the Calapooia River and tributary streams can pose a significant problem for fish populations. Dams and road crossing culverts are examples of potential fish passage barriers that are present in the watershed. Fish move through the river channel and tributary streams through phases of their life cycle and in response to changing conditions. When there is a barrier to fish passage fish cannot access important areas for spawning or move into cool tributary streams when the Calapooia River or other streams warm during the summer months. Fish passage barriers can totally block fish movement during all times or they can partially block movement for periods associated with high or low stream flows. Partial fish passage barriers can significantly slow the migration of spring chinook salmon and winter steelhead through the river. Fish will often hold in pools at the base of a barrier waiting for conditions to change, creating problems such as stress on the fish, delaying migration, providing opportunities for poaching and predation.

Fish passage barriers on the lower Calapooia River: Migrating fish encounter significant passage problems between river mile 19.5 and 28.5 of the Calapooia River. At this location, there is a complex of dams and diversion ditches associated with Thompson's Mill. Historically, water was diverted through the Mill for producing flour and, more recently, generating electricity. A series of dams and ditches (Sodom and Thompson Diversion Ditch), divert the Calapooia River's flow, which creates problems for migrating fish. During late winter and early spring high flows, more of the river's water passes through Sodom Ditch and less water flows through the natural Calapooia River channel. Migrating winter steelhead move through Sodom Ditch and pass over the fish ladder at Sodom Dam. As flows drop in late spring the Mill needs more of the water to continue generating electricity [the mill, no owned by the State of Oregon, is no longer used to generate electricity]. The Mill operators [formerly] manage Sodom Dam to divert more of the river's flow into the Calapooia River channel. Late migrating spring Chinook salmon are delayed moving over the fish ladder at Sodom Dam. Water falling over the apron of the dam creates a "false attraction" to the base of the dam, delaying fish movement into the fish ladder.

Fish passage issues within the Thompson's Mill complex have been recognized since the 1960s. Recently, a working group formed to help identify options for addressing the fish passage problems and explore ways to maintain the historic mill. The Thompson's Mill Working Group, comprised of the Mill's owner, state and federal agencies, the Calapooia Watershed Council, and other stakeholders, has pursued immediate actions to address fish passage issues while working to identify and study solutions. Currently, the Mill operates under a "non-generation" agreement that compensates the owner for not producing electricity during the river's low flow periods in the late spring and summer when fish passage is priority [since the State of Oregon purchased Thompson's Mills, it is no longer used for electricity generation]. Under this agreement, currently more water flows into Sodom Ditch, improving passage for spring Chinook salmon moving through the ditch. The Working Group is seeking continued funding to maintain the non-generation agreement until a final solution can be agreed on by all stakeholders.

During recent years, the non-generation agreement has allowed the river to flow into Sodom Ditch. Typically this means approximately 2/3's of the flow goes down the Sodom and 1/3 goes down the natural Calapooia River channel. However, the channel substrate changes from year to year and impacts the shape of the Calapooia channel entrance and in some years gravel deposits at the entrance of the Calapooia channel force more of the flow down the Sodom Ditch channel.

The following fish passage, spawning and river flow issues within the Thompson's Mill complex will require more investigation:

(1) Fish passage at the dams: Fish encounter problems moving over Sodom Dam. The dam may delay winter steelhead moving upstream, and it presents significant obstacles to spring Chinook salmon because they must pass over the dam in the late spring when river flows have dropped. Water flowing over the dam creates velocities that attract adult spring Chinook salmon to the base of the dam, which inhibits efficient passage through the fish ladder. As a result, spring Chinook will hold for a period of time in the pool at the base of the dam, delaying their migration to spawning locations in the upper watershed. The delayed spring Chinook are vulnerable to harassment and poaching. The Thompson's Mill Working Group is contracting for a study to examine the fish passage problems at the dams and to identify options for improved dam and fish ladder designs.

(2) Steelhead spawning in Sodom Ditch: Winter steelhead have been observed spawning in Sodom Ditch. Pacific lamprey have also been seen spawning in the ditch. It is not known why the fish are spawning in the area when suitable gravels are present in the river reaches immediately upstream. It may be that some winter steelhead spawn in the ditch because they are delayed trying to bypass the Thompson's Mill. Spawning in the ditch is a concern because the juvenile winter steelhead probably do not survive the high summer water temperatures in this reach of the river (ODFW 2003).

(3) Calapooia River channel: During the winter and spring high flow periods, most of the river's discharge flows through Sodom Ditch. This dramatic reduction in high flows moving through the Calapooia River has changed the river channel and associated floodplain within this reach of the river. The river channel has narrowed and, because there is reduced flooding, homes have been

built in the historic floodplain. With these changes, there are limited alternatives for increasing high flows through the Calapooia River channel. The Thompson's Mill Working Group is examining alternative water allocation through the river channel and Sodom Ditch and the implications for fish migration, aquatic habitat, and future operation of the Mill.

3.4.3. Winter Steelhead and Spring Chinook Periodicity

Table 3-4 includes a graphical summary life stage periodicity for winter steelhead and spring Chinook in the Calapooia River. Both species use the river year-round for juvenile rearing.

Table 3-4. The fish periodicity chart for the Calapooia River in the project area.

Species	Life Stage	Jan		Feb		Mar		Apr		May		June		Jul		Aug		Sept		Oct		Nov		Dec	
		1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31
Winter Steelhead	Upstream Migration																								
	Spawning[1]																								
	Incubation[1]																								
	Juvenile Rearing[2]																								
	Smolt Outmigration																								
Spring Chinook	Upstream Migration																								
	Spawning[3]																								
	Incubation[3]																								
	Juvenile Rearing[2]																								
	Smolt Outmigration																								
Calapooia River Statistical Flows @ bifurcation (Avg Daily Flow)[4]		**1,193**		**1,065**		**879**		**637**		**396**		**199**		**77**		**42**		**48**		**152**		**662**		**1,159**	
Calapooia River Statistical Flows @ bifurcation (Min Daily Flow)		**55**		**42**		**127**		**18**		**84**		**40**		**24**		**15**		**11**		**12**		**116**		**19**	
Flow Management Policy Paper - DRAFT										70	70	70	70	70											
										50 Sodom / 20 Calapooia					**Ecological Maintenance Flows**					**Transition to Fish Passage**					
		Demonstration Milling with Hydromechanical Power																			Demonstration Milling				

[1] Periodicity is for general basin characteristics, Steelhead spawning and incubation in Sodom Ditch is considered an anomaly for the Calapooia River

[2] Juvenile rearing may be precluded during low flow periods of August - October due to water depth and high temperatures

[3] Periodicity is for general basin characteristics, Chinook do not spawn or incubate in the Sodom Ditch reach of the Calapooia

[4] Flows from Tetra Tech Technical Memorandum (May 9, 2008)

3.5. Land Use

The following section is largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004).

Agriculture and forestry are the dominant land uses within the Calapooia River Watershed. Forests and other natural vegetation (wetlands, riparian, and other areas) cover the largest proportion of the watershed (53%). Agricultural crops comprise approximately 45% of the watershed's area. Grass seed crops dominate agricultural production, occupying more than 23% (including burned grass) of the watershed's area, primarily located in the lower watershed below Brownsville. Built areas (residential and commercial development) occupy the smallest proportion of the watershed (less than 2%).

3.6. Limiting Factors

The following section is largely taken from the Calapooia River Watershed Assessment (Calapooia Watershed Council 2004).

There are several conditions that are believed to limit fish populations in the Calapooia River. These limiting factors include fish passage barriers, historical logging practices, water quality, water temperatures, and habitat degradation.

There are two components constraining the passage of fish in the Calapooia River Watershed: fish passage barriers at dams in the river channel, and fish passage issues at road crossing culverts. Dams are the most pressing fish passage issue. The Calapooia River, in comparison to tributary streams, provides most of the important fish habitat, particularly for spring Chinook salmon and winter steelhead trout. The river is the primary corridor for migrating fish and the river channel provides most of the important spawning and rearing habitat. The river's dams – within the Thompson's Mill complex – delay fish moving upstream to spawning areas in the upper watershed and may prevent the movement of adult and juvenile fish during parts of the year. Delaying the migration of spring Chinook and winter steelhead stresses the fish, leading to reduced spawning success, and provides opportunities for poaching and harassment.

Historically, there were frequent and large log drives down the lower and middle Calapooia River. These log drives and the associated removal of wood and log jams, probably continue to affect the river channel by limiting the current quantity of instream wood. The reduced number of logs and other wood in the river's channel limit the creation of pools and hiding habitat for fish. The loss of wood from the river channel is further exacerbated by current wood removal as logs continue to be removed from the Calapooia River and tributary streams (Figure 3-5). Logs are removed to prevent bank erosion, reduce damage to property and bridges, and, in some cases, to allow recreational boaters to pass down the channel (Robert Singleton, Corvallis Canoe and Kayak Club, personal communication, 2003). In addition, the lack of large trees growing along some sections of the river and streams contributes to the long-term shortage of wood in channels. The status of streamside forests and the wood removal actions have cumulatively impacted the river channel and fish habitat quality, reducing the formation of pools, limiting hiding cover, and slowing the trapping of spawning gravels. More wood throughout the river and stream system would be helpful. A targeted approach to in-channel wood restoration and riparian area enhancement would be to target the most responsive reaches of the river and the lower portions of tributary streams. The river reaches near Brownsville are areas of active gravel deposition that would be especially responsive to short-term actions to protect current wood in the channel and promote future activities that support enhanced riparian areas.

The quality of the water throughout the Calapooia River Watershed influences its use by fish, wildlife, and humans. Excessive values for water temperature, suspended sediment, nitrogen, phosphorus, and pesticides can make portions of the watershed unfavorable for some species fish and wildlife, especially during the summer when these species are most stressed and water levels are low. Excessive bacteria levels in the water can make the water more difficult to treat for drinking and increase the risk of infection for those who swim and angle in the river. The Calapooia River is included in the 303(d) list as water quality limited for temperature, as a result of the river exceeding the water quality standard of 64 °F in its lower reaches. The Calapooia River is on the 303(d) list for bacteria, as well as temperature. Consequently, it is subject to a TMDL process for bacteria.

Grass seed farming is an important agricultural occupation in the Calapooia River watershed (Figure 3-6). Improving agricultural practices would address nitrogen fertilizer runoff to the river. Compared to cultivated riparian zones, non-cultivated riparian zones are very effective at removing nitrogen from subsurface water draining into a stream. However, due to flow patterns and the speed of surface runoff, while retaining riparian vegetation is generally beneficial to streams, the benefits do not include mitigating nitrogen runoff. The most effective means to control nitrogen runoff from grass seed fields begin with applying only the minimum amount of fertilizer needed to grow a crop and that the timing of the fertilizer coincide with periods of drier weather.

Figure 3-6. A grass seed field paralleling the Calapooia River. The site is characterized by a minimal riparian buffer separating the river from agricultural production.

Water temperatures recently measured throughout the watershed are probably similar to natural patterns, except along some tributaries. The main channel of the river is wide throughout much of its length, and even if mature conifers and hardwoods again grew along the banks, the trees would still not provide much shade to the summer channel. Rapid regrowth of trees along those upper watershed forest streams that were once harvested of trees, combined with current regulations for retaining wide buffers of trees during timber harvest, means that shading levels are high on forest land. Shade is sparser along streams in agricultural and urban areas, and is most critical to providing cool water refuge for fish during the summer months. Brush Creek is an example of a year-round stream that is suitable, to some extent, for supporting winter steelhead and trout during the summer, but could be made cooler and more productive if streamside vegetation was restored along selected reaches that are currently grazed by cattle and horses.

Where rivers have been treated in such a way, conflicts among landowners and declines in fish habitat invariably occur (Figure 3-7). In addition, stopping the meandering on one segment of river usually causes an upstream or downstream increase in meandering and erosion, often creating problems for neighboring landowners. By decreasing the meandering of a river, water velocity increases, the river bottom downcuts, gravel bars become coarser, and zones of still water decrease; all of which are detrimental to fish. Treating a bank to control meandering can not be justified on the grounds of decreasing overall river sediment loads, since the amount of bank material is so small compared to the river's overall sediment load.

Figure 3-7. Working with landowners to maintain riparian vegetation buffers between residences (left) and agricultural fields (right) would reduce sediment loading to the Calapooia River and slow property loss.

3.7. Summary

In summary, the Calapooia River has been impacted by 150 years of development that has brought changes to the river corridor and greater watershed. Addressing fish passage barriers on the lower Calapooia River as part of the Thompson's Mills complex will improve ecosystem connectivity and fish movement through the migration corridor. Other limiting factors including habitat and land use impacts would benefit from working with private landowners throughout the watershed.

4 RIVER CORRIDOR CONDITIONS

The following sections present information from the river reconnaissance, geomorphic surveys, and remote sensing completed by RDG. Information is provided at both the project area scale as well as for the four reaches.

4.1. River Corridor and Geomorphology Overview

The 10.8 mile project area was delineated into four reaches based on stream type, infrastructure and river diversions (Figure 4-1). The four delineated reaches include the following.

- Reach 1: Calapooia River-Sodom Ditch bifurcation to the Interstate-5 bridge
- Reach 2: The Interstate-5 Bridge to Shear Dam
- Reach 3: Shear Dam to the Thompson's Mills spillway return
- Reach 4: Thompson's Mills spillway return to Butte Creek

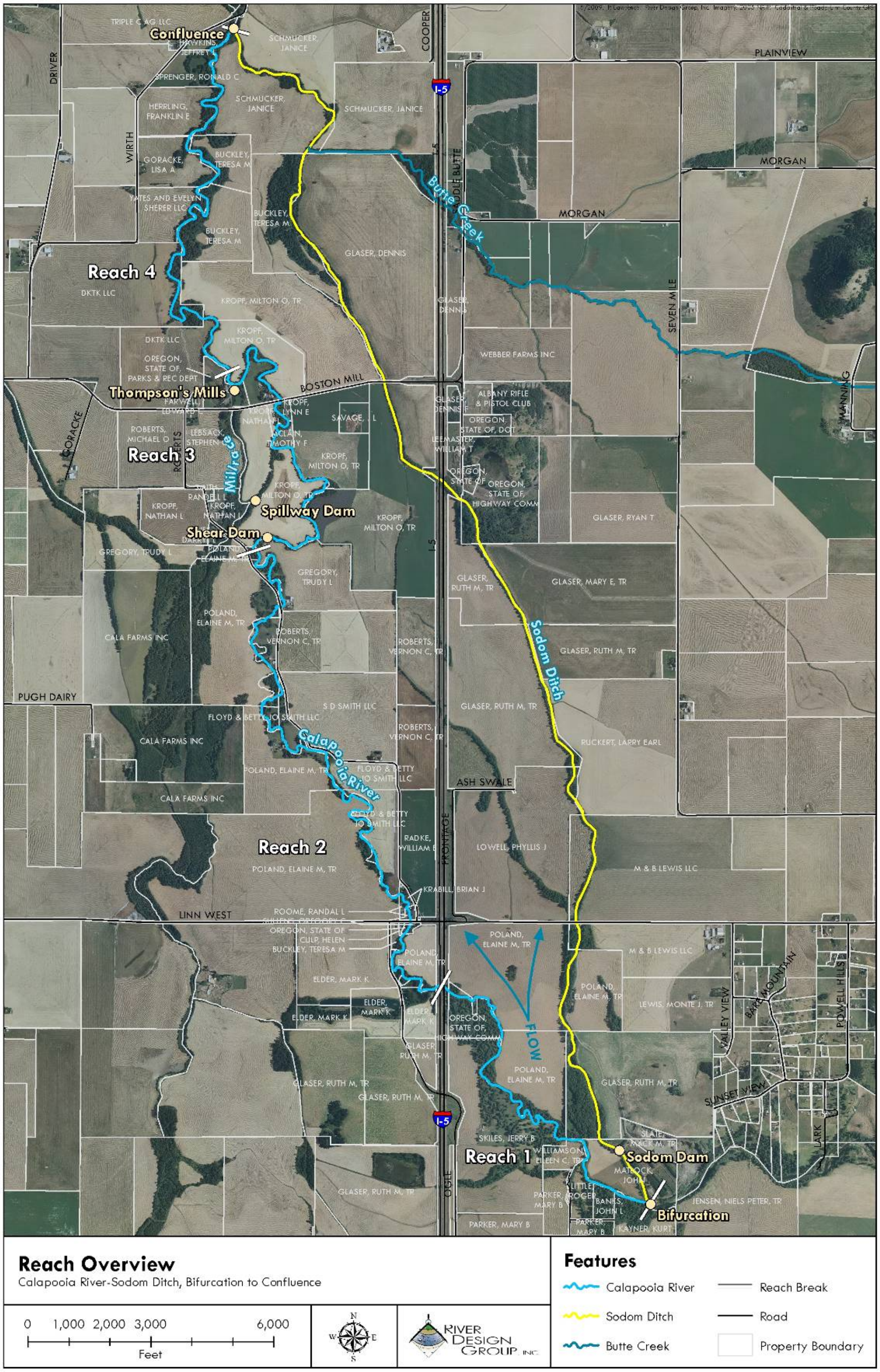

Figure 4-1. The Calapooia River project area.

Table 4-1 includes descriptive statistics for the four survey reaches in the study area.

Table 4-1. Reach dimensions, dominant Rosgen stream type, and general characteristics for the Calapooia River study area.

Reach	Stream Type	Channel Length (miles)	Valley Length (miles)	Channel Sinuosity	General Reach Characteristics
Reach 1	F6	2.04	1.39	1.47	Pool-riffle, bank erosion, incised channel
Reach 2	F/C	3.71	2.20	1.69	Backwater deposition, diffuse channel network
Reach 3	F6	2.23	0.84	2.65	Entrenched channel, stable banks and veg
Reach 4	F/E	2.78	1.60	1.75	Entrenched channel, reference condition
Total	N/A	10.76	6.03	1.78 (ave)	

The existing morphology of the Calapooia River is affected by land use and flow regulation practices that have altered channel hydraulic and sediment transport characteristics. Flow management has decreased the volume of flow routed to the Calapooia River resulting in a reduction in channel cross-sectional area. Additionally, the supply of sediment available to the Calapooia River downstream of the bifurcation point has decreased due to deposition in the bifurcations area and sediment routing to Sodom Ditch. Modified hydrology including the frequency, magnitude, and duration of channel-forming flows and flood events has created varied morphological conditions that are divergent from the historical pre-management river morphology. The variation in channel capacity and river hydraulics is primarily related to the split flow condition created by the bifurcation of the Calapooia River and Sodom Ditch. In addition to Sodom Dam, other diversion structures and river management operations have also influenced the channel morphology.

Stream types present in the Calapooia River project area varied based on channel capacity. Channel capacities are related to channel hydraulics, sediment deposition, and vegetation encroachment. Diversion dams influence stream power, either promoting channel aggradation or degradation. This pattern is evident upstream (aggradation) and downstream (degradation) of diversion structures. In sum, the location of diversion structures and how the Calapooia River has been managed in the past, influences river hydraulics and channel morphology.

4.1.1. Geology

The geology of the Calapooia River project area is comprised of an underlying formation of Tertiary period pyroclastic rocks and balsatic flows overlaid by Quaternary alluvium and Willamette silts (Beaulieu 1974). The Calapooia River channel migration zone is dominated by alluvium derived from the Calapooia River (Figure 4-2). The alluvium, similar to other tributaries in the Willamette Valley, ranges in depth but is typically tens of feet think and comprised of gravel, sand and silt. Thinner veneers of silt and clay are also common.

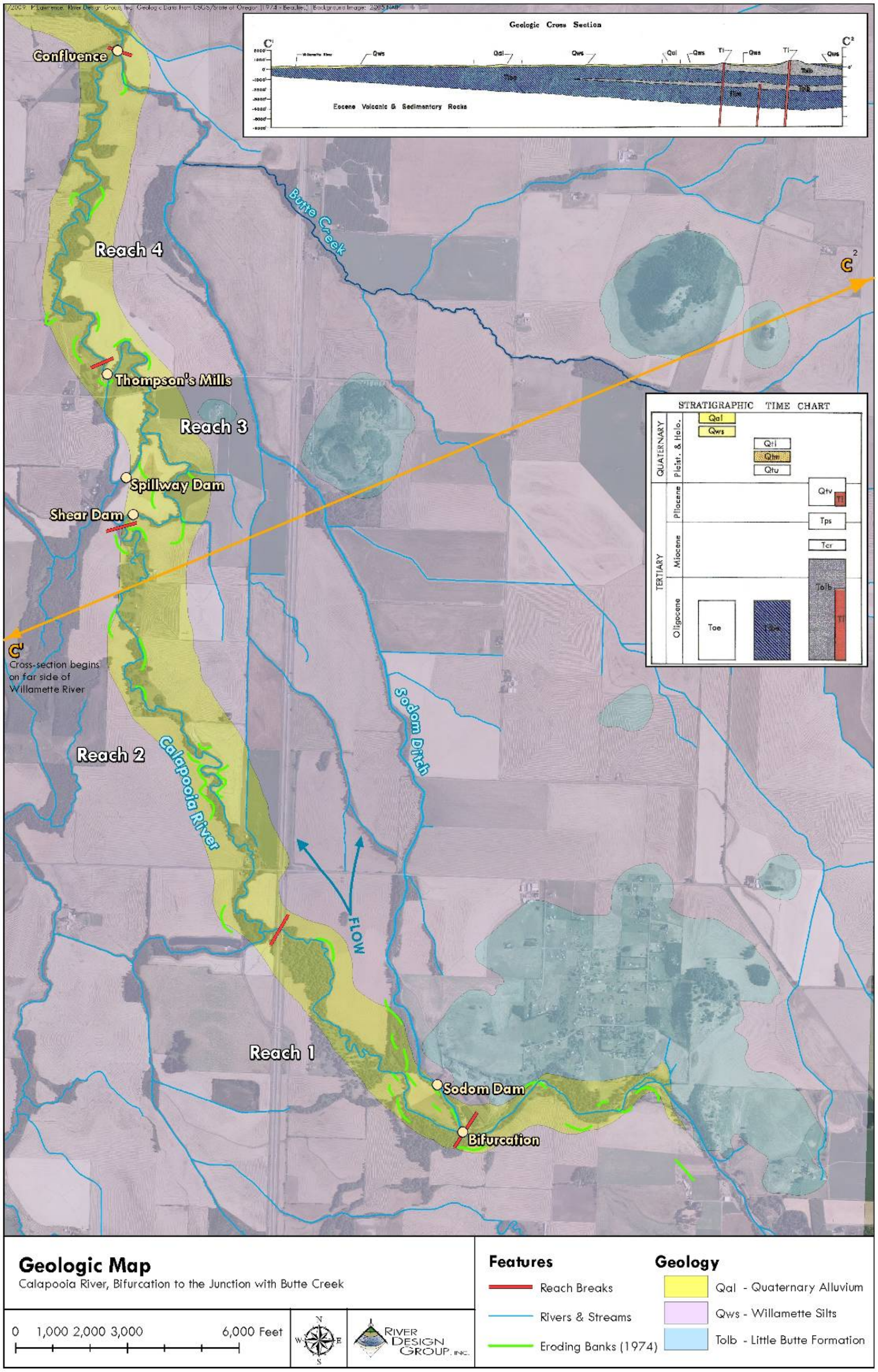

Figure 4-2. Calapooia River project area geology.

The geology outside of the Calapooia River migration zone is dominated by Willamette silts and narrower distributions of Quaternary alluvium. Willamette silts range from 20 ft to 30 ft in depth and are comprised of quartzo-feldspathic silts, silty clays,and clays of lacustrine and glacial flood water origin. Surficial erratic and heavy minerals indicate Columbia River source, perhaps suggesting the influence of historical flooding related to the period ice dam breaks of Glacial Lake Missoula. Carbon-14 dating reveals these materials to range in age from 19,000 to 34,000+ years, further supporting a relationship with Glacial Lake Missoula.

The Little Butte Formation comprised of dacitic and andesitic pyroclastic rocks and dense, dark, basaltic flow rock, dates to the Oligocene and early Miocene. Exposed buttes to the east of the project area are remnants of volcanoes that existed in geologic time.

4.1.2. Soils

Soils layers were downloaded from several sources to evaluate soil properties. The 2006 SSURGO soils layer was downloaded and overlayed on the 2005 NAIP imagery (Figure 4-3). The area of each soil map unit located in the project area was quantified (Table 4-2). The top five soil map units in adjacent to the Calapooia River and Sodom Ditch were quantified. Soil descriptions are included for the top map units adjacent to the Calapooia River and Sodom Ditch.

Table 4-2. Soil map units and taxonomic subgroups for soils adjacent to the Calapooia River and Sodom Ditch in the project area.

		Calapooia River		Sodom Ditch	
Map Unit Name	Taxonomic Subgroup	Area (acres)	Percent of Total Area	Area (acres)	Percent of Total Area
Chehalis silty clay loam	Cumulic Ultic Haploxerolls	194.1	19%	46.2	14%
Coburg silty clay loam	Pachic Ultic Argixerolls	178.1	17%	3.9	1%
Malabon silty clay loam	Pachic Ultic Argixerolls	173.1	17%		0%
McBee silty clay loam	Cumulic Ultic Haploxerolls	172.4	17%	23.4	7%
Wapato silty clay loam	Fluvaquentic Haplaquolls	138.1	13%	9.9	3%
Conser silty clay loam	Typic Argiaquolls	61	6%	12.4	4%
Chapman Loam	Cumulic Ultic Haploxerolls	28.2	3%		0%
Cloquato silt loam	Cumulic Ultic Haploxerolls	27.4	3%		0%
Newberg fine sandy loam	Fluventic Haploxerolls	23.2	2%	0.6	0%
Woodburn Silt Loam	Aquultic Argixerolls	11.1	1%	6.8	2%
Awbrig silty clay loam	Vertic Albaqualfs	8.8	1%	23	7%
Fluvents-Fluvaquents complex	NA	6	1%	12.8	4%
Dayton silt loam	Typic Albaqualfs	4.9	0%	0.8	0%
Whiteson Silt Loam	Fluvaquentic Haplaquolls		0%	111.6	33%
Amity Silt Loam	Argialbolls		0%	3.2	1%
Bashaw silty clay	Typic Pelloxererts		0%	2.9	1%
Waldo silt clay loam	Fluvaquentic Haplaquolls		0%	83.3	24%
Total		1026.4	100%	340.8	100%

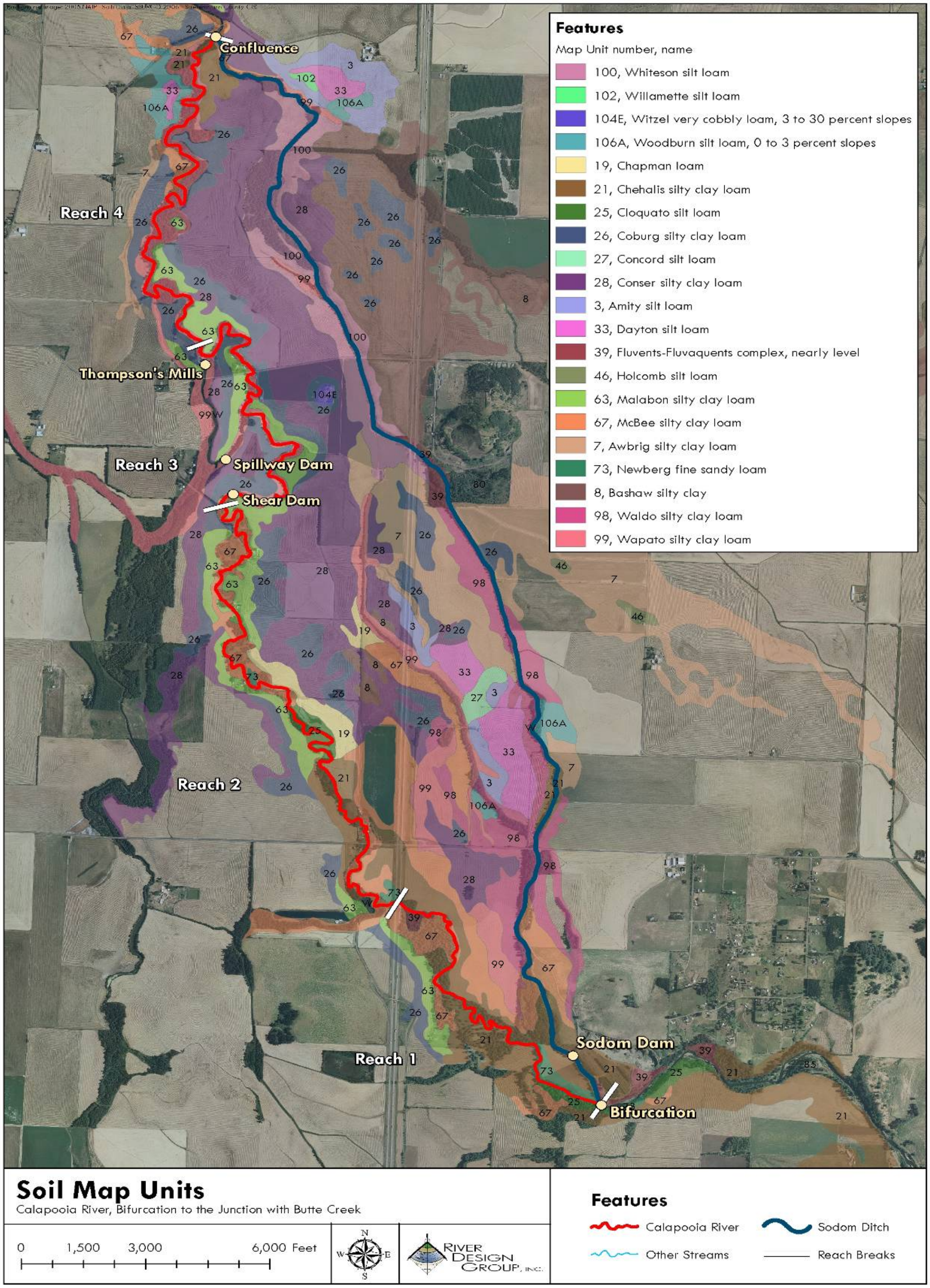

Figure 4-3. Soil map units in the project area.

Calapooia River Soil Map Units

A 500 ft wide buffer centered on the Calapooia River channel was processed for the project area to quantify soil map units bordering the Calapooia River. The top soil units adjacent to the Calapooia River are described in the following text. The narrative is taken from the Linn County Soil Survey (Langridge 1987).

Chehalis silty clay loam (19% of project area)
This deep, well drained soil is on floodplains. It formed in moderately fine textured recent alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly conifers, hardwoods, shrubs, and grasses. Permeability of this Chehalis soil is moderate. Available water capacity is about 10 to 13 inches. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of erosion is slight except during occasional, brief periods of flooding from November to March. This unit is used mainly for hay, pasture, small grain, orchards, and vegetables. It is also used for homesite development, wildlife habitat, and recreation. If this unit is used for cultivated crops, the main limitation is the susceptibility to occasional, brief periods of flooding. The soil in this unit is sticky and plastic when wet, which restricts trafficability. Cover crops are needed to protect the soil from erosion during periods of flooding in winter. Grazing when the soil is moist results in compaction of the surface layer, poor tilth, and excessive runoff. A proper stocking rate, pasture rotation, and restricted grazing during wet periods help to keep the pasture in good condition and to protect the soil from erosion.

This soil unit is most common from the bifurcation through the first third of Reach 2. This soil unit has a discontinuous distribution through this area, bordering both sides of the river.

Coburg silty clay loam (17% of project area)
This deep, moderately well-drained soil is in nearly level to slightly convex areas on low alluvial stream terraces. It formed in silty and clayey alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly conifers, hardwoods, shrubs, and grasses. Elevation is 200 to 600 feet. Permeability of this Coburg soil is moderately slow. Available water capacity is about 10 to 12 inches. Effective rooting depth is 60 inches or more; however, penetration of roots is restricted by a seasonal high water table. Runoff is slow, and the hazard of erosion is slight. A seasonal high water table is at a depth of 1.5 to 2.5 feet from November to May. This unit is used mainly for small grain, grass seed, orchards, pasture, and vegetables. It is also used for homesite development, wildlife habitat, and recreation. If this unit is used for crops, the main limitation is wetness as a result of the seasonal high water table. Most climatically adapted crops can be grown if artificial drainage is provided. Deep-rooted crops are suited to areas where the natural drainage is adequate or where a drainage system has been installed. If a suitable outlet is available, subsurface drainage can be used to reduce wetness.

This soil unit is distributed throughout the project area although it is more common downstream from Shear Dam. The soil unit is generally more distant from the current channel location, often separated from the river by floodplain soils.

Malabon silty clay loam (17% of project area)
This deep, well-drained soil is in nearly level to slightly convex areas on low alluvial stream terraces. It formed in silty and clayey alluvium derived from mixed sources. Slopes are 0 to 3 percent. The vegetation in areas not cultivated is mainly conifers, hardwoods, shrubs, and grasses. Elevation is 200 to 600 feet. The average annual precipitation is 40 to 50 inches, the average annual air temperature is 52 to 54°F, and the average annual frost-free period is 165 to 210

days. The risk of erosion is increased if the soil is left exposed during site development. Preserving the existing plant cover during construction helps to control erosion.

Malabon soils border the Calapooia River floodplain from Reach 1 downstream to below Thompson's Mill. This soil unit's distribution is limited to a mile-long strip to the west of the Calapooia River in Reach 1. It becomes more common downstream of Linn West Road, forming a near-continuous distribution through Thompson's Mill. Malabon soils are typically buffered from the river by Chehalis and McBee soil units.

McBee silty clay loam (17% of project area)
This deep, moderately well drained soil is on floodplains. It formed in moderately fine textured alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly conifers, hardwoods, shrubs, and grasses. Elevation is 150 to 600 feet. The average annual precipitation is 40 to 50 inches, the average annual air temperature is 52 to 54°F, and the average frost-free period is 165 to 210 days. Permeability of this McBee soil is moderate. Available water capacity is about 11 to 13 inches. Effective rooting depth is 60 inches; however, root penetration may be restricted by a seasonal high water table. Runoff is slow, and the hazard of erosion is slight except during occasional periods of flooding from November to May. A seasonal high water table is at a depth of 2 to 3 feet from November to April. This unit is used mainly for hay, pasture, small grain, vegetables, and orchards. It is also used for homesite development, wildlife habitat, and recreation. If this unit is used for cultivated crops, the main limitation is the hazard of flooding. Most climatically adapted crops can be grown if the soil is protected from flooding late in spring and early in summer.

The soil in this unit is sticky and plastic when wet, which restricts trafficability. Conducting field operations during periods when the soil is wet reduces tilth and destroys structure, which results in increased runoff and erosion. Grazing when the soil is moist results in compaction of the surface layer, poor tilth, and excessive runoff. Proper stocking rate, pasture rotation, and restricted grazing during wet periods help to keep the pasture in good condition and to protect the soil from erosion. Cover crops are needed to protect the soil from erosion during periods of flooding in winter.

The McBee soil unit is common in the downstream portion of Reach 1 and through Reach 2 to Shear Dam. Downstream of Shear Dam, the McBee soil unit is replaced by the Wapato soil unit. The McBee soil unit's characteristics reflect river influence.

Wapato silty clay loam (14% of project area)
This deep, poorly drained soil is in old abandoned river channels and depressional areas of flood plains. It formed in moderately fine textured recent alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly conifers, hardwoods, shrubs, grasses, and sedges. Elevation is 150 to 600 feet. The average annual precipitation is 40 to 50 inches, the average annual air temperature is 52 to 54°F, and the average frost-free period is 165 to 210 days. Permeability of this Wapato soil is moderately slow. Available water capacity is about 10 to 12 inches. Effective rooting depth is 60 inches; however, root penetration may be restricted by a seasonal high water table. Runoff is slow to ponded, and the hazard of erosion is slight except during frequent periods of flooding from December to April. A seasonal high water table is at a depth of 1 foot above the surface to 1 foot below the surface from November to May. This unit is used mainly for small grain, hay, pasture, and grass seed. If this unit is used for crops, the main limitations are wetness and the hazard of flooding. Drainage is

needed if this unit is to be used to its maximum potential. Unless the soil is drained, long-lived, deep-rooted deciduous fruit and nut trees, strawberries, caneberries, and alfalfa are adversely affected by wetness. Response to drainage is good if adequate outlets are available.

The Wapato soil unit is most common soil unit bordering the Calapooia River from Shear Dam to the confluence with Butte Creek. Due to the degree of river influence in the soil unit's formation, Wapato silty clay loam is only found adjacent to the river and tributaries in the project area.

Calapooia River Soils Unit Summary

The trend of floodplain soils from well-drained soils in Reach 1 to poorly drained soils in Reach 4 reflects the flattening valley slope, increased inundation, and lower stream energy of the system. The Wapato silty clay loam soil is saturated during winter high water and is slow to drain. These conditions support native plant species including alder, Oregon ash, cottonwood, willow, rose, and sedges. Coburg and Malabon soil units characterize moderately well-drained to well-drained low alluvial terraces that border lower elevation floodplains in the river corridor.

Sodom Ditch Map Units

A 250 ft wide buffer centered on Sodom Ditch was processed for the project area to quantify soil map units bordering Sodom Ditch. A narrower buffer was selected for Sodom Ditch due to Sodom Ditch's straighter channel planform relative to the Calapooia River. The top soil units adjacent to Sodom Ditch are described in the following text. The narrative is taken from the Linn County Soil Survey (Langridge 1987).

Whiteson Silt Loam (33% of project area)

This deep, somewhat poorly drained to poorly drained soil is on floodplains. It formed in medium textured recent alluvium overlying fine textured, older alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly hardwoods, shrubs, and grasses. Elevation is 200 to 700 feet. The average annual precipitation is 40 to 60 inches, the average annual air temperature is 52 to 54°F, and the average frost-free period is 165 to 210 days. Permeability of this Whiteson soil is very slow. Available water capacity is about 5 to 7 inches. Effective rooting depth is 60 inches; however, root penetration may be restricted by the dense clay layer and a seasonal high water table. Runoff is slow, and the hazard of erosion is slight except during frequent periods of flooding from December to April. A seasonal high water table is at a depth of 0 to 1 foot from November to May.

This unit is used mainly for hay, pasture, and grass seed. The main limitations are wetness and the hazard flooding. This unit generally is not suited to deep-rooted perennial crops, because adequate drainage usually cannot be maintained in winter and spring. Drainage is needed if this unit is to be used to its maximum potential. Drainage is difficult and expensive because the dense clay requires close spacing of the tile drains.

The Whiteson silt loam soil type is the dominant soil unit bordering Sodom Ditch from Interstate-5 downstream to the confluence with Butte Creek. This soil unit is characterized as a poorly drained floodplain soil, suggesting the influence of alluvial processes in its formation.

Waldo silt clay loam (24% of project area)

This deep, poorly drained soil is in depressional areas of the high floodplains and low alluvial stream terraces. It formed in silty and clayey alluvium derived from mixed sources. Slope is 0 to 3 percent. The vegetation in areas not cultivated is mainly hardwoods, shrubs, sedges, rushes, and grasses. Elevation is 250 to 900 feet. The average annual precipitation is 40 to 60 inches, the average annual air temperature is 52 to 54°F, and the average frost-free period is 165 to 210 days. Permeability of this Waldo soil is slow. Available water capacity is about 9 to 11 inches. Effective rooting depth is 60 inches; however, root penetration may be restricted by the dense clay layer and a seasonal high water table. Runoff is slow, and the hazard of erosion is slight except during periods of flooding. A seasonal high water table is at a depth of 0 to 0.5 foot from November to May. This soil is subject to occasional periods of flooding from January to April.

This unit is used mainly for small grain, grass seed, and hay and pasture. If this unit is used for crops, the main limitations are wetness and the hazard of flooding. Drainage is needed if this unit is to be used to its maximum potential. If a suitable outlet is available, subsurface drainage can be used to reduce wetness. Drainage is difficult and expensive because the dense clay requires close spacing of the tile drains.

The Waldo silt clay loam soil unit extends from midway through Reach 1 to the Interstate-5 crossing. The characteristics of this soil type suggest that the soil unit is typical of high floodplains and alluvial terraces rather than lower floodplains. These properties reflect the recent history of Sodom Ditch.

Chehalis silty clay loam (14% of project area)
Soil properties for this soil unit are presented in the Calapooia River soil map units discussion. Along Sodom Ditch, the Chehalis soil unit is primarily located from the bifurcation point downstream to the start of the Waldo silt clay loam soil unit. The distribution of the Chehalis unit is an extension of the soils that are located along the Calapooia River in the same area.

McBee silty clay loam (7% of project area)
Soil properties for this soil unit are presented in the Calapooia River soil map units discussion. The McBee soil unit is limited to the middle portion of Reach 1. The soil unit borders the east side of Sodom Ditch and is located between the upstream Chehalis soil unit and the downstream Waldo soil unit.

Awbrig silty clay loam (7% of project area)
This deep, poorly drained soil is in slightly concave areas on low alluvial stream terraces. It formed in silty and clayey alluvium derived from mixed sources. Slope is 0 to 2 percent. The vegetation in areas not cultivated is mainly hardwoods, shrubs, grasses, sedges, and rushes. Elevation is 200 to 600 feet. The average annual precipitation is 40 to 50 inches, the average annual air temperature is 52 to 54°F, and the average frost-free period is 165 to 210 days. Permeability of this Awbrig soil is very slow. Available water capacity is about 7 to 9 inches. Effective rooting depth is more than 60 inches; however, penetration of roots is restricted by the dense clay and seasonal high water table. Runoff is slow to ponded, and the hazard of erosion is slight. A seasonal high water table is at a depth of 0.5 foot above the surface to 1.0 foot below the surface from November to May. This soil is subject to rare periods of flooding.

This unit is used mainly for grass seed, hay, pasture, and small grain. If this unit is used for crops, the main limitation is wetness. This unit generally is not suited to deep-rooted perennial crops, because adequate drainage usually cannot be maintained in winter and spring. Drainage is needed if the soil in this unit is to be used to its maximum potential. Open ditches and tile drains can be used to remove excess water on the surface. Tile drains have limited suitability for removing subsurface water from the soil because of the very slow permeability and inadequate outlets. If a suitable outlet is available, subsurface drainage can be used to reduce wetness. Drainage of the soil is difficult and expensive because the dense clay requires close spacing of the tile drains. Where tile drains have been properly installed and maintained, however, they have functioned properly for more than 10 years.

The Awbrig silty clay loam is located on terraces adjacent to Sodom Ditch through Reach 2. Although the soil unit interfaces with Sodom Ditch in two locations, it is generally separated from Sodom Ditch by the Waldo silty clay loam soil unit.

Sodom Ditch Soil Units Summary
Soil units bordering Sodom Ditch are characterized by conditions related to high floodplains and low alluvial terraces (Waldo) and floodplains (Whiteson). Soil units are more continuous along Sodom Ditch relative to the greater diversity and discontinuous distribution of soil units adjacent to Calapooia River. These patterns reflect differences in the age and dynamism of Sodom Ditch and the Calapooia River. The recent creation of Sodom Ditch (late 1800s) is reflected in the more continuous soil unit distributions. Soil properties related to abandoned river channels (e.g. Wapato soil unit) have not formed along Sodom Ditch.

4.1.3. Riparian Vegetation Extent

Changes in the extent of riparian vegetation was evaluated using Landsat imagery and historical air photos. The Landsat imagery spanned a period of 14 years (1987 to 2001) and allows a coarse comparison of vegetation changes over time. In generally, vegetation over this period appeared to remain relatively consistent with several areas of increased vegetative growth including the vicinity of the Reeach1-Reach 2 break, the area east of the Spillway Dam and near the confluence of the Calapooia River and Butte Creek.

Review of historical air photos suggests that the riparian zone narrowed over time as the Calapooia River corridor was developed for agriculture. While the riparian community has experienced substantial reduction since 1936, much of the floodplain was already developed by that point. In general, native riparian vegetation has been displaced by agricultural fields. Native vegetation displacement has included both full removal and thinning of the riparian canopy. Decreased riparian density may be related to loss of canopy trees, grazing of floodplain areas, or displacement of canopy-forming species by invasive vegetation such as Himalayan blackberry and Scotch broom. The historical channel comparison map highlights several areas that have experienced riparian vegetation conversion.

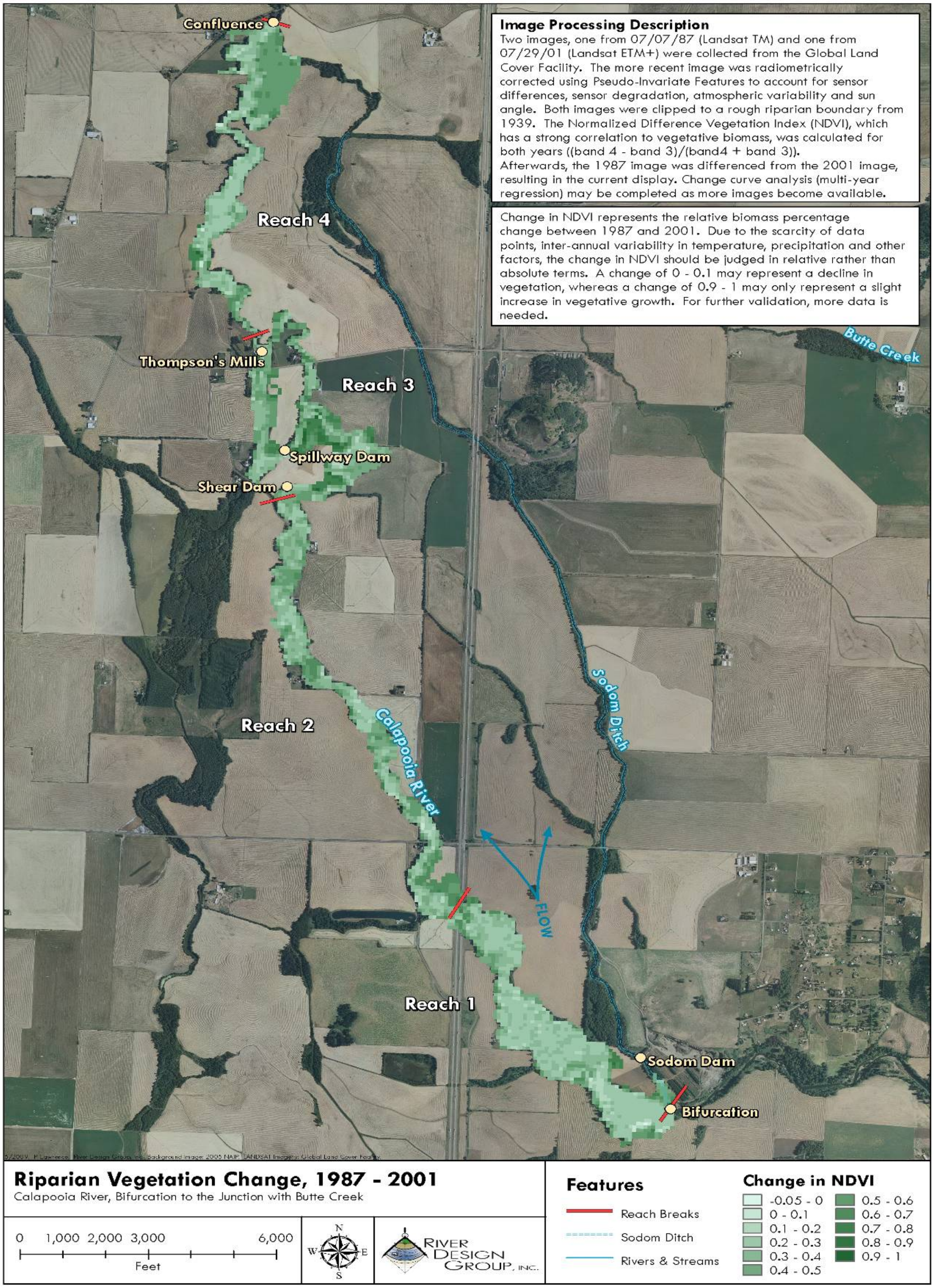

Figure 4-4. Riparian vegetation change from 1987 to 2001 in the project area.

4.1.4. Historical Aerial Photo Analysis

The following sections review the changes in the channel planform over time. The data set includes the 1853 GLO maps which are not considered to be very accurate. In addition to the 1853 map, air photos from 1936, 1956, 1967, 1991, and 2005 were also reviewed. Summary plan form statistics were calculated for each reach over the historical record to evaluate changes in the planform morphology. Figure 4-5 provides an overview of the historical channel locations in the project area. Figure 4-6 provides a more detailed perspective of the historical channel locations in the four reaches of the Calapooia River.

Reach 1

Reach 1 morphological changes are similar to trends observed throughout the project area. Average radius of curvature and average meander length increased 141% and 18%, respectively from 1936 to 2005 (Table 4-3). The increase in the radius of curvature is the greatest change of the four reaches. In Reach 1, belt width has been fairly consistent through time, exhibiting only a 1percent decrease over the 70-year period of analysis. Sinuosity, however, has decreased 27 percent, representing the greatest change in sinuosity of the four reaches. These results are due largely to two channel oxbow meanders that were present in 1936 and disconnected from the primary channel by 1956 (upstream site – STA 60+00) and 1967 (downstream site (STA 87+00). The upstream meander cut-off may have been a natural channel avulsion as land uses did not change in the vicinity of the channel change. The oxbow meander occurs on a middle terrace feature, approximately 3 ft above the present base elevation of the Calapooia River. The downstream site was modified for the construction of Interstate 5 completed in 1966 (Kirchmeier 1989). The straightening of the Calapooia River channel at Interstate-5 truncated two meanders and reduced the channel length by several hundred feet. Similar to the upstream meander oxbow, the vertical elevation difference between the bed of the oxbow meander and present channel ranges from 3 ft to 5 ft, suggesting the degree of channel bed degradation that has occurred since 1966 on this section of the Calapooia River. These sizeable avulsions increased the river's energy gradient. Figure 4-7 includes a graphical comparison of the channel planform variables descriptive statistics. Figure 4-8 provides a comparison of Reach 1 over the photo record.

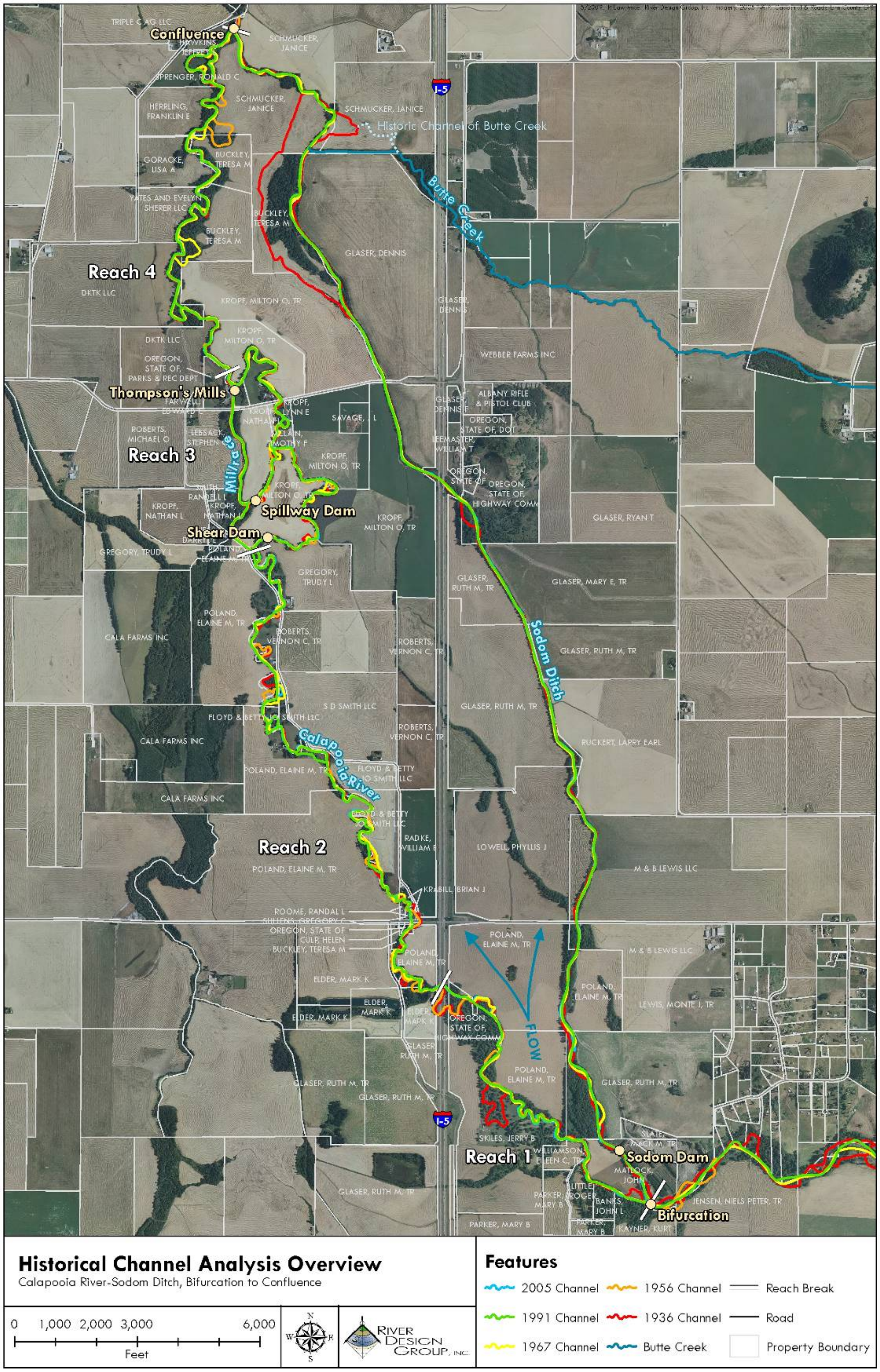

Figure 4-5. The historical channel analysis overview for the project area.

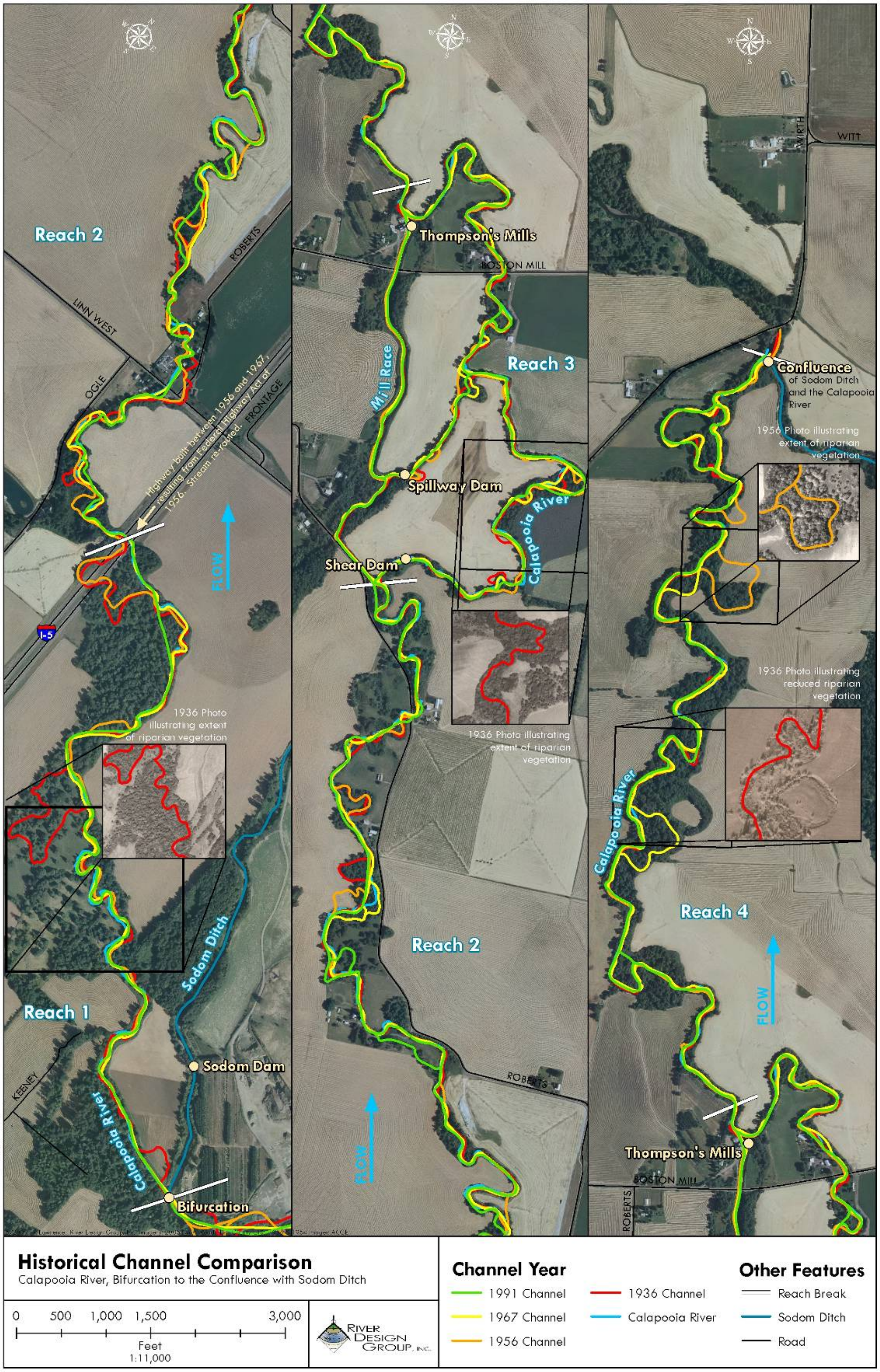

Figure 4-6. A comparison of the historical locations of the Calapooia River and Sodom Ditch since 1936.

Table 4-3. Channel planform metrics for Reach 1 of the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
1853	Min	84.9	200.2	94.7	1.22
	Max	744.5	1292.9	340.4	
	Mean	322.1	606.6	155.3	
	Std Dev	136.8	234.6	46.1	
	Sample Size	30	35	31	
1936	Min	17.5	97.5	35.1	2.02
	Max	516.3	785.0	451.0	
	Mean	70.4	394.1	150.7	
	Std Dev	69.8	150.4	91.0	
	Sample Size	52	54	51	
1956	Min	26.3	171.0	39.3	1.55
	Max	541.9	798.6	379.3	
	Mean	133.8	377.9	134.8	
	Std Dev	117.5	134.5	74.5	
	Sample Size	48	46	47	
1967	Min	26.4	152.0	31.0	1.40
	Max	890.1	832.2	449.3	
	Mean	183.5	431.4	140.1	
	Std Dev	185.4	171.7	81.7	
	Sample Size	41	39	40	
1991	Min	26.1	181.6	43.6	1.40
	Max	1034.2	1172.1	306.1	
	Mean	192.8	522.5	150.7	
	Std Dev	193.6	240.0	77.6	
	Sample Size	32	32	32	
2005	Min	31.4	162.1	55.8	1.47
	Max	715.6	884.6	291.5	
	Mean	169.5	465.3	148.6	
	Std Dev	160.7	196.0	64.7	
	Sample Size	37	36	37	

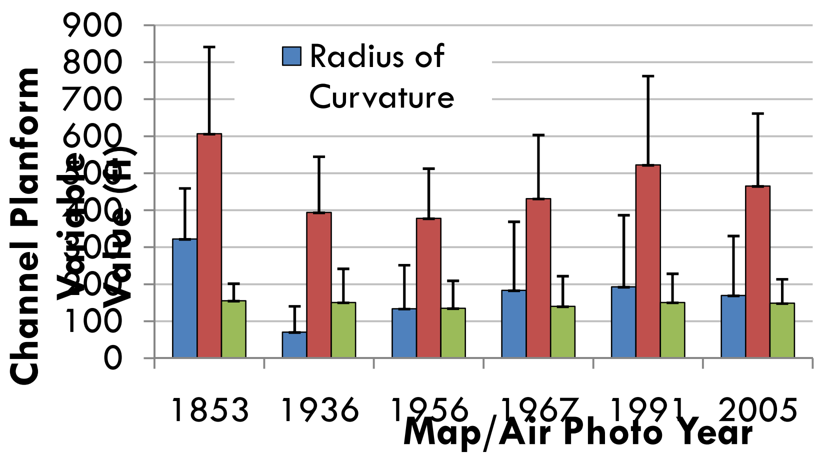

Figure 4-7. A comparison of the radius of curvature, meander length, and belt width for Reach 1 over the map/air photo history.

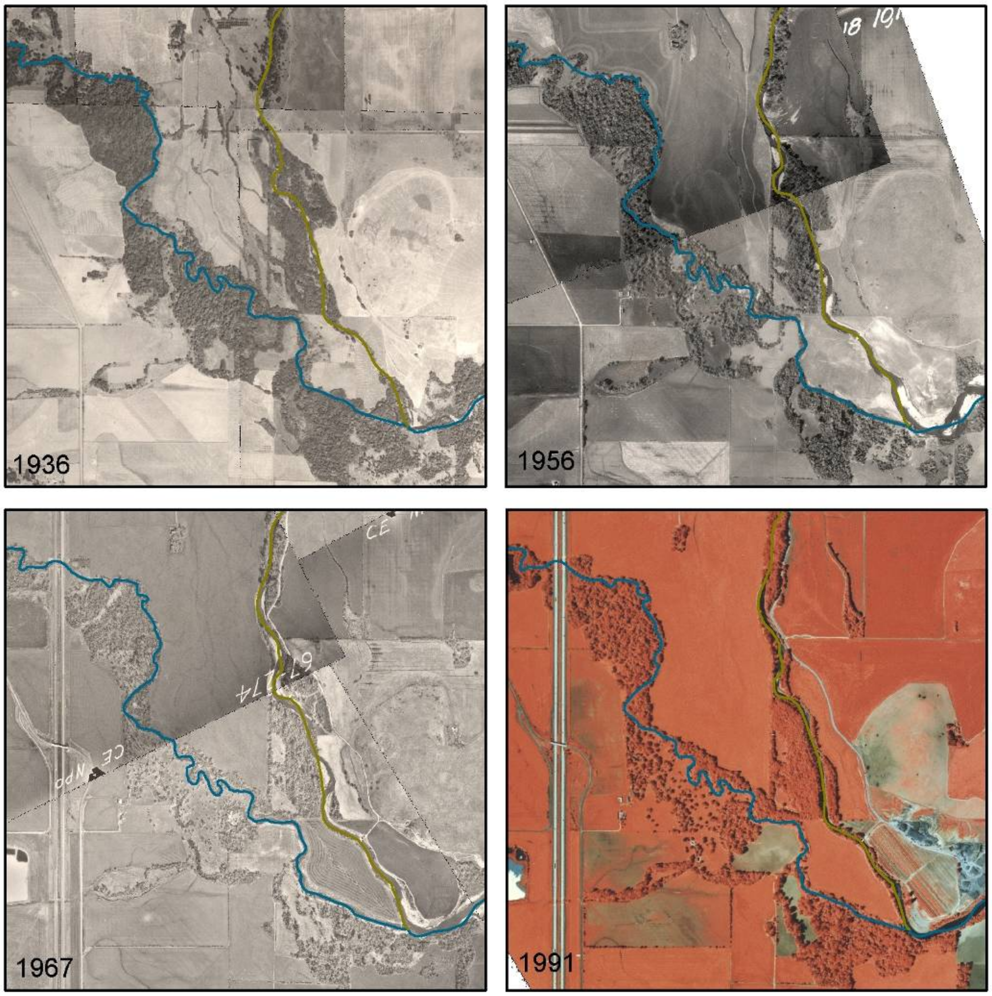

Figure 4-8. Historical photograph time series for Reach 1. Current channel alignments for the Calapooia River and the Sodom Ditch are shown in blue and brown, respectively. A loss of riparian vegetation and widening of the Sodom Ditch are evident over time.

Reach 2

The changes observed in Reach 2 are also similar to the assessment reach as a whole. Radius of curvature, meander length, and belt width have increased 39 percent, 23 percent, and 7 percent, respectively. Sinuosity has decreased 7 percent in Reach 2. The historical channel comparison indicates that several channel meanders that were present in 1936 and 1956 are no longer part of the primary channel in Reach 2. In addition, the extent of the riparian vegetation has decreased dramatically over time, which may in part explain some of the changes in planform metrics that are observed in this reach.

Historical photographs indicate that riparian vegetation in Reach 2 was already sparse by 1936. By 2005, vegetation is further reduced, and there is currently a narrow band of vegetation along the Calapooia River channel margins. Agricultural land uses are extended to channel margins in Reach 2. Linn West Drive crosses the Calapooia River near the beginning of Reach 2 and was present as early as 1936 based on the aerial photo analysis. Table 4-4 and Figure 4-9 provide a summary of the channel planform data.

Table 4-4. Channel planform metrics for Reach 2 of the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
1853	Min	67.8	302.8	103.9	1.39
	Max	969.0	1892.8	610.7	
	Mean	407.0	974.2	240.2	
	Std Dev	230.7	456.9	130.2	
	Sample Size	38	35	39	
1936	Min	21.2	172.8	45.2	1.81
	Max	352.6	738.7	597.3	
	Mean	82.3	421.6	200.4	
	Std Dev	65.8	142.9	113.5	
	Sample Size	75	71	73	
1956	Min	14.4	96.9	28.5	1.66
	Max	325.7	836.3	606.8	
	Mean	82.3	390.0	172.1	
	Std Dev	63.4	171.3	112.8	
	Sample Size	73	77	74	
1967	Min	16.5	125.4	36.7	1.64
	Max	457.0	854.0	622.3	
	Mean	91.6	378.6	165.7	
	Std Dev	80.6	150.2	117.8	
	Sample Size	73	75	73	
1991	Min	17.9	140.4	44.2	1.65
	Max	256.8	1146.0	662.0	
	Mean	77.7	397.4	177.5	
	Std Dev	54.4	185.0	112.9	
	Sample Size	78	75	78	
2005	Min	21.4	163.9	64.0	1.69
	Max	799.6	1637.1	642.2	
	Mean	114.7	517.7	214.6	
	Std Dev	128.1	274.7	132.3	
	Sample Size	54	52	53	

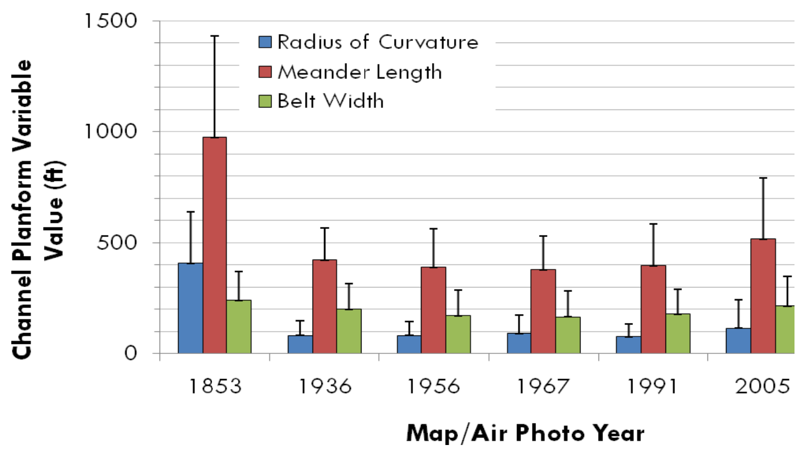

Figure 4-9. A comparison of the radius of curvature, meander length, and belt width for Reach 2 over the map/air photo history.

Reach 3

Reach 3 has remained relatively unchanged over the period of record. The greatest change observed from historical photos is a 42 percent increase in radius of curvature. In comparison, meander length and belt width in Reach 3 have increased 18 percent and 14 percent, respectively, while sinuosity has decreased 4 percent. Reach 3 has the greatest overall sinuosity of all the reaches, with 2005 sinuosity estimated at 2.65.

From the historical channel comparison, Reach 3 has changed relatively little over time. This may be due in part to channel confinements at bridges and roads, in particular Roberts Road and Boston Mill Drive. In addition, Reach 3 contains Thompson's Mills millrace, which is not a natural river channel, and does not display the same changes over time that would be expected in a natural system. The millrace splits to the west from the Calapooia River at the beginning of Reach 3. Approximately 150 ft downstream on the Calapooia River is the Shear Dam, which raises the water level to supply water to the millrace (OPRD 2006). The extent of riparian vegetation in the reach was fairly consistent between 1936 and 1956, but was increasingly displaced by the 1967 air photo. Table 4-5 and Figure 4-10 summarize the channel planform data for Reach 3.

Table 4-5. Channel planform metrics for Reach 3 of the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
1853	Min	153.8	397.1	107.0	1.31
	Max	791.9	1790.3	950.4	
	Mean	372.2	875.1	300.4	
	Std Dev	189.6	350.6	186.9	
	Sample Size	14	18	22	
1936	Min	27.3	112.3	43.4	2.76
	Max	157.5	939.6	510.3	
	Mean	72.5	401.6	184.6	
	Std Dev	36.5	223.6	104.5	
	Sample Size	35	40	35	
1956	Min	26.5	124.7	44.5	2.76
	Max	267.0	896.5	502.7	
	Mean	83.3	402.2	158.0	
	Std Dev	52.6	197.2	101.6	
	Sample Size	38	41	36	
1967	Min	24.4	164.5	41.6	2.70
	Max	319.9	1037.6	495.8	
	Mean	87.4	402.7	181.5	
	Std Dev	66.3	210.6	118.9	
	Sample Size	39	40	38	
1991	Min	27.9	206.3	77.1	2.62
	Max	383.3	996.7	777.4	
	Mean	111.2	541.5	227.4	
	Std Dev	77.2	211.7	146.7	
	Sample Size	35	29	35	
2005	Min	21.8	207.7	61.8	2.65
	Max	523.9	922.5	490.3	
	Mean	103.3	474.6	211.3	
	Std Dev	96.9	169.7	117.9	
	Sample Size	29	33	28	

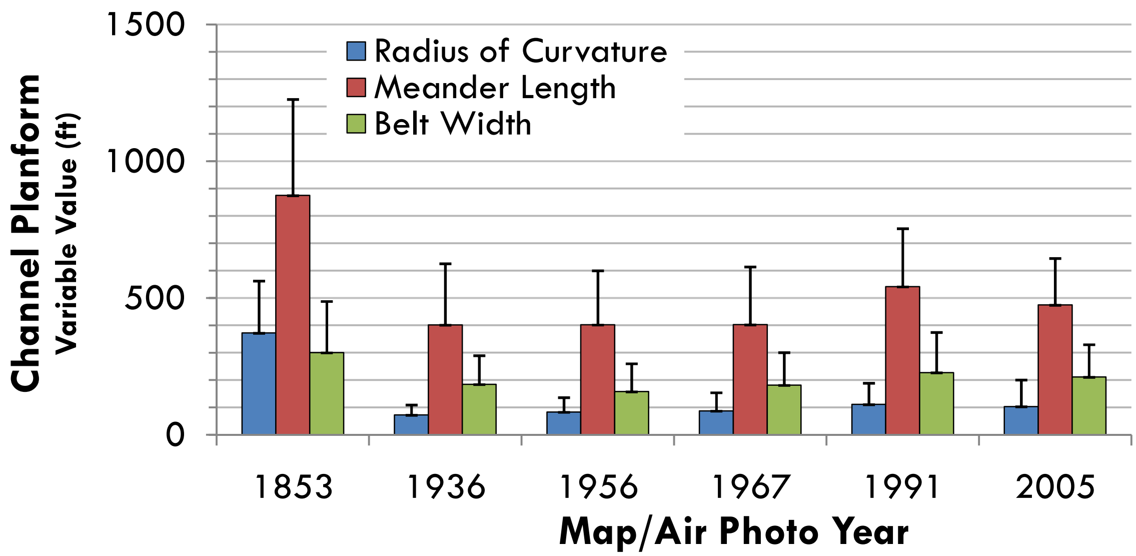

Figure 4-10. A comparison of the radius of curvature, meander length, and belt width for Reach 3 over the map/air photo history.

Reach 4

Reach 4 has exhibited increases in all planform metrics over time. Radius of curvature, meander length, and belt width have increased 41 percent, 45 percent, and 25 percent, respectively since 1936. The increases in meander length and belt width are the greatest percent changes of any of the four reaches. Sinuosity has remained relatively consistent, increasing 0.6 percent between 1936 and 2005. Although sinuosity increased from 1.73 to 1.92 between 1936 and 1956, by 2005 it decreased approximately 9 percent to 1.74.

Review of the historical aerial photographs indicates that riparian vegetation decreased substantially in Reach 4 near the junction of the Sodom Ditch and Butte Creek between 1967 and 1991. The extent of riparian vegetation on the Calapooia River was fairly consistent between 1936 and 1956, decreased from 1956 to 1991, and remained relatively unchanged from 1991 until 2005. A small drainage network that is evident in the 1956 aerial photograph is not visible in the 1991 photograph. Similar to Reach 1, numerous oxbow meanders situated on terrace features are present on the landscape in Reach 4 (STA 430+00 and STA 490+00). The aerial photo series indicates these features were abandoned between 1967 and 1991. Table 4-6 and Figure 4-11 display the summary data for the Reach 4 channel planform statistics.

Table 4-6. Channel planform metrics for Reach 4 of the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
1853	Min	153.8	397.1	107.0	1.31
	Max	791.9	1790.3	950.4	
	Mean	372.2	875.1	300.4	
	Std Dev	189.6	350.6	186.9	
	Sample Size	14	18	22	
1936	Min	27.3	112.3	43.4	2.76
	Max	157.5	939.6	510.3	
	Mean	72.5	401.6	184.6	
	Std Dev	36.5	223.6	104.5	
	Sample Size	35	40	35	
1956	Min	26.5	124.7	44.5	2.76
	Max	267.0	896.5	502.7	
	Mean	83.3	402.2	158.0	
	Std Dev	52.6	197.2	101.6	
	Sample Size	38	41	36	
1967	Min	24.4	164.5	41.6	2.70
	Max	319.9	1037.6	495.8	
	Mean	87.4	402.7	181.5	
	Std Dev	66.3	210.6	118.9	
	Sample Size	39	40	38	
1991	Min	27.9	206.3	77.1	2.62
	Max	383.3	996.7	777.4	
	Mean	111.2	541.5	227.4	
	Std Dev	77.2	211.7	146.7	
	Sample Size	35	29	35	
2005	Min	21.8	207.7	61.8	2.65
	Max	523.9	922.5	490.3	
	Mean	103.3	474.6	211.3	
	Std Dev	96.9	169.7	117.9	
	Sample Size	29	33	28	

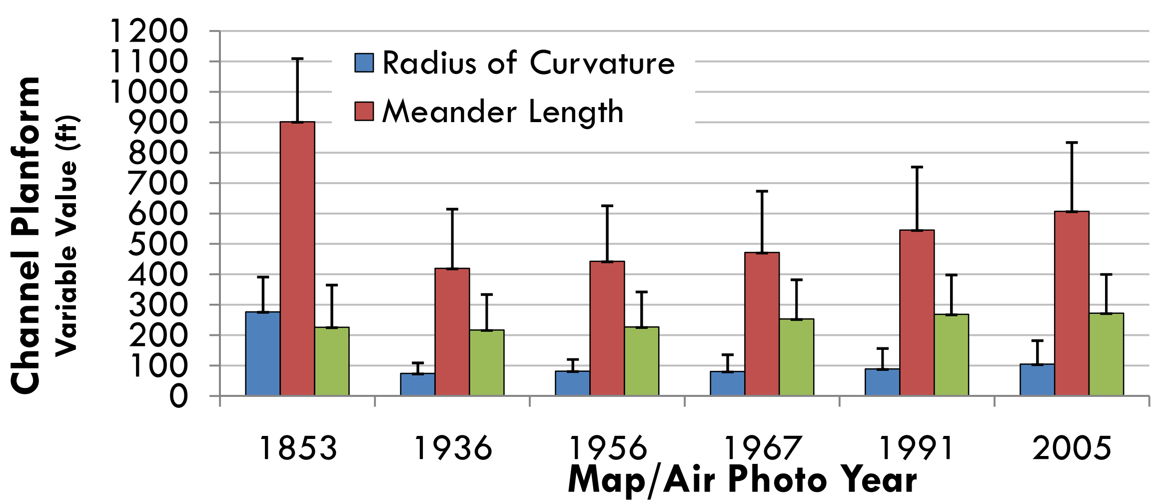

Figure 4-11. A comparison of the radius of curvature, meander length, and belt width for Reach 4 over the map/air photo history.

Channel Planform Summary

The results of the historical air photo review suggest the Calapooia River has straightened over time from a more tortuous channel pattern in 1936 to a straighter alignment in 2005 (Table 4-7 and Figure 4-12). The Calapooia River has experienced a loss of 1.5 miles of channel length since 1936. Planform metrics suggest there has been an increase in the three metrics used to evaluate planform morphology. The radius of curvature has increased from a low of 76 ft in 1936 to a high of 124 ft in 2005, a 63 percent increase. Meander length has increased 25 percent over time, from 410 ft in 1936 to 514 ft in 2005. Belt width has also increased slightly over time, from 188 ft in 1936 to 211 ft in 2005. This relatively minor increase (12 percent) indicates that the width of the river corridor has been relatively constant over time, but lateral erosion may be responsible in part for lateral extension of the meander belt width. Finally, sinuosity has decreased 13 percent, from 2.05 in 1936 to 1.79 in 2005. This is significant, because channels with high sinuosity create a greater number of ponds, islands, alcoves, side channels, and gravel bars than do straighter channels. As a result, highly sinuous channels tend to have more habitat niches that are beneficial for fish and wildlife at various life stages.

Channel straightening is related to both human influences and natural river processes. Human influences have included straightening the river for road crossings, removal of riparian vegetation and floodplain development for agriculture, and channel modifications for surface water management. The channel straightening trend is also related to increased rates of down-valley meander migration that increases the distance between meander arcs (pools). Greater meander lengths suggest fewer pools are located in the project reach. Additionally, the higher radius of curvature suggests that pools are more elongate and perhaps do not generate the same degree of scour that is responsible for maintaining deeper pools. These changes are attributed to channel modifications and the loss of riparian vegetation that has decreased the channel boundary's resistance to erosion and meander migration.

Table 4-7. Channel planform metrics for the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
1853	Min	67.8	200.2	94.7	1.34
	Max	969	1892.8	950.4	
	Mean	360.7	814.6	226	
	Std Dev	193.2	387.6	139.1	
1936	Min	17.5	97.5	35.1	2.05
	Max	516.3	985.9	597.3	
	Mean	75.9	410.5	188.2	
	Std Dev	58	175.3	110.1	
1956	Min	14.4	96.9	28.5	1.94
	Max	541.9	1159.4	606.8	
	Mean	94.4	403	173.7	
	Std Dev	77.3	174.3	108.8	
1967	Min	16.5	125.4	31	1.83
	Max	890.1	1043	622.3	
	Mean	107.2	416.2	183.6	

Table 4-7. Channel planform metrics for the Calapooia River.

Map/Air Photo Year	Statistic	Radius of Curvature (ft)	Meander Length (ft)	Belt Width (ft)	Sinuosity (ft/ft)
	Std Dev	112.1	184.4	121.5	
1991	Min	17.9	140.4	43.6	1.8
	Max	1034.2	1172.1	777.4	
	Mean	106.5	475.8	201.2	
	Std Dev	107.9	216.5	126	
2005	Min	21.4	162.1	55.8	1.79
	Max	799.6	1637.1	642.2	
	Mean	123.5	513.6	210.8	
	Std Dev	125.6	232.9	123.1	

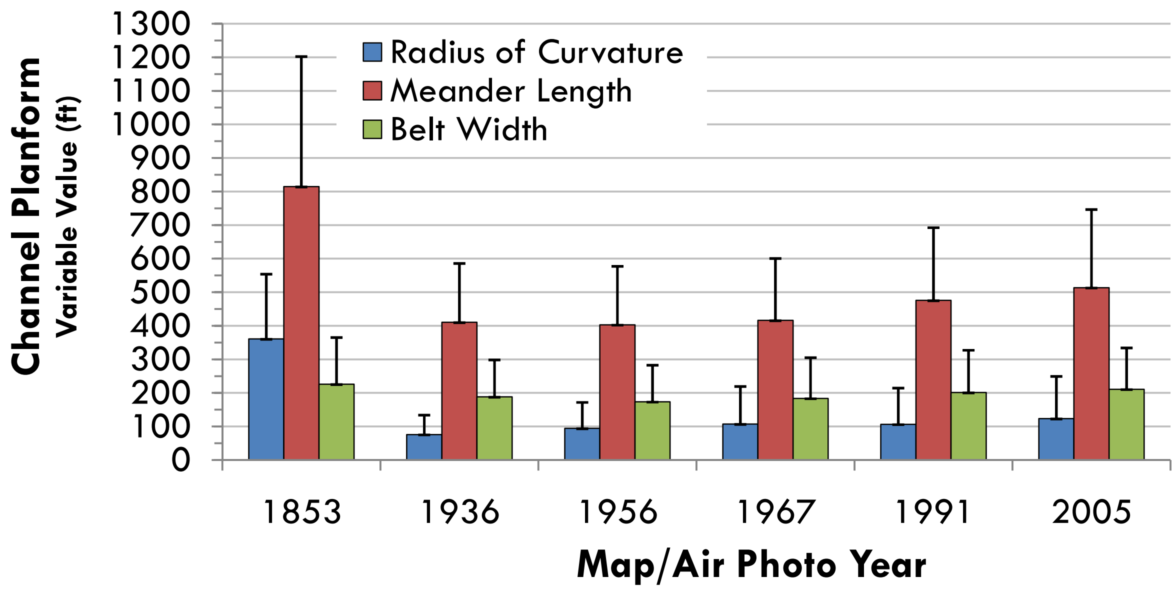

Figure 4-12. A comparison of the radius of curvature, meander length, and belt width for the Calapooia River project area over the map/air photo history.

4.2. Reach Descriptions

The following sections summarize the channel morphology, land use, and infrastructure in the Calapooia River project area. Figure 4-13 is a map of the project area and includes channel survey locations.

4.2.1. Reach 1 – Bifurcation to Interstate-5 Bridge

Reach Overview

Reach 1 extends 2.04 miles from the Calapooia River-Sodom Ditch bifurcation downstream to the Interstate-5 bridge on the Calapooia River. The channel morphology in Reach 1 is characterized as a silt-clay dominated, plane bed river. Historically, the bifurcation area was dredged periodically to remove deposited sediment. Flashboards were seasonally installed in Sodom Dam to direct flows to the Calapooia River for hydroelectric power generation. Dredging and dam management activities have not occurred since the purchase of Thompson's Mills by the State of

Oregon in 2002. Since 2002, sediment and large wood have accumulated in the bifurcation area, promoting more flow down Sodom Ditch than the Calapooia River. This process has lead to increased conveyance down the Sodom Ditch with a corresponding reduction in the Calapooia River's channel capacity throughout the project area. The modified flow regime appears to have prolonged the vegetation growing season, promoting vegetation establishment below the bankfull elevation in the active channel. Inset vegetated surfaces, colonized by reed canarygrass, woody species, and invasives such as Himalayan blackberry, appear to reduce the channel's hydraulic capacity by increasing bed resistance, reducing velocities and increasing river stage.

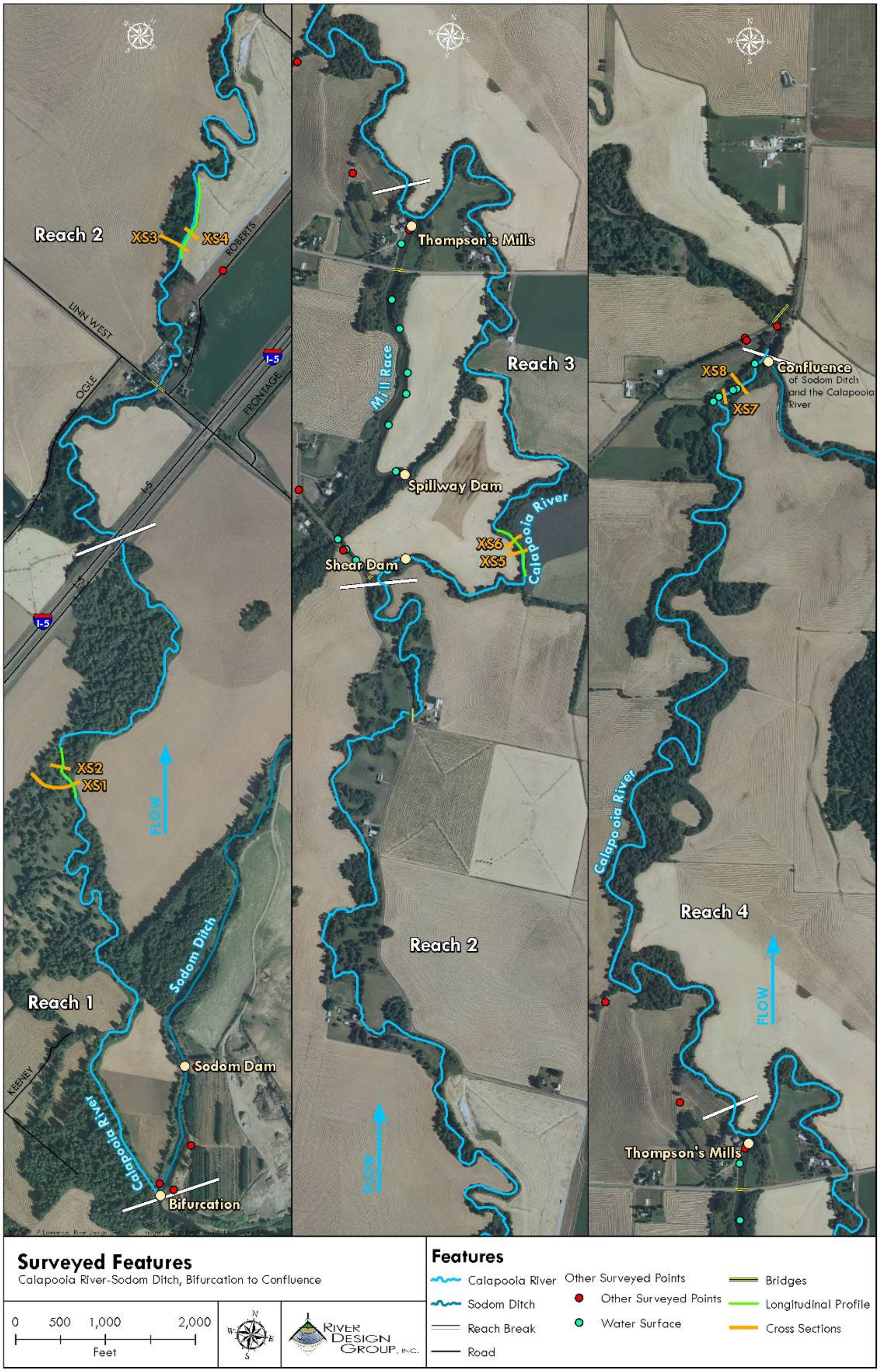

Figure 4-13. Survey locations in the Calapooia River project area.

The width of the riparian zone varies in Reach 1, but is typically broader than in the three delineated downstream reaches. Vegetation was characterized by Oregon ash, birch, maple, black cottonwood, red osier dogwood and Himalayan blackberry. Trees and riparian vegetation form a narrow band along the channel, and the width of the riparian buffer, while greater than other reaches in the study area, was limited. Numerous relict side channels and oxbows were observed during field data collection and attest to the altered hydrologic regime and/or degree of bed degradation that has occurred over time. It is unclear if the oxbows features were hydrologically connected to the channel prior to construction of Sodom Ditch. However, the oxbows appear to have been mechanically truncated from the main channel system. Older black cottonwood forest galleries occupying terrace surfaces also attest to the former elevation of the Calapooia River's floodplain. New cottonwood establishment is limited to younger age classes that are scoured annually from raw, mobile flood deposits in the active channel. Levee systems border portions of the active channel and are constructed of river alluvium and angular stone. The levees were installed to reduce the frequency of overbank flooding in Reach 1 of the project area.

Large wood and vegetation influence the channel morphology through the reach. Channel-spanning large wood influences lateral channel stability by either deflecting flows into or away from streambanks. In locations, large wood channel spanning assemblages reduced the channel's capacity and exacerbated bank erosion upstream of the structure. Numerous sediment sources and bank erosion site were documented on meander outcurves and bends in Reach 1.

The historical aerial photo analysis indicates that the river's location has remained relatively consistent since the 1930s with the exception of two primary areas where the channel has straightened over time. The downstream area was affected by the construction of Interstate-5 in the 1950s. One meander sequence was cut-off to align the channel with the bridge opening. It is unclear why the Calapooia River abandoned the historical channel at the upstream site, though this occurred between the 1936 and the 1956 photos. Numerous oxbow meanders present in the upper portion of Reach 1 attest to a channel system that was likely characterized by a primary bankfull channel with multiple secondary channels that distributed flows across a broad floodplain surface. Meander oxbows were not contiguous with the channel system in the 1936 photo series.

Channel and Floodplain Morphology

The channel morphology in Reach 1 is characterized silt-clay dominated, plane bed river. The altered flow regime resulting from the split flow condition and management of both the bifurcation and Sodom Dam has modified the magnitude and duration of channel-forming flows in the Calapooia River. These changes are expressed in the morphology and riparian vegetation patterns. Figure 4-14 displays the typical cross-section morphology of the valley (left cross-section) and channel (right cross-section) in Reach 1. Oxbow meander features are present on terraces bordering the Calapooia River (R1XS1 between STA 0+50 and STA 1+00). Based on hydraulic modeling, these features are likely activated periodically during moderate to high flow events. Based on the surveyed valley cross-section and difference in elevation between the elevation of the oxbow meander and existing Calapooia River streambed, the Calapooia River may have been mechanically dredged (Figure 4-11, R1XS2) to lower the base elevation and/or channelized to optimize agricultural production on the south side of the river corridor. Figure 4-15 illustrates typical river corridor conditions in Reach 1.

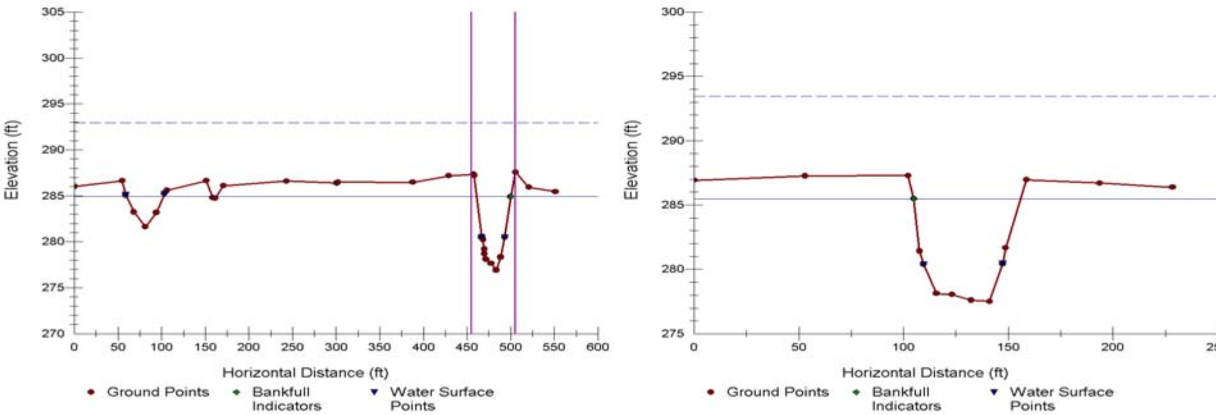

Figure 4-14. Typical channel cross-sections in Reach 1. R1XS1 (left) is located at STA 1+50 and R1XS2 (right) is located at STA 3+98 on the Reach 1 longitudinal profile. R1XS2 is more entrenched and maintains a larger cross sectional-area.

Figure 4-15. Typical channel conditions (left) and a sediment source (right) in Reach 1. The riparian corridor includes native species, invasive vegetation, and agricultural fields.

Channel cross-section dimensions are summarized in Table 4-8. Channel cross-sectional area ranged from 203.8 ft^2 to 307.7 ft^2 with corresponding mean depths of 5.3 ft and 6.0 ft, respectively. Entrenchment ratios, or the ratio of the floodprone width to bankfull width, ranged from 4.5 to 14.2. As demonstrated by the hydraulic modeling performed by TetraTech (2008) and RDG (this report), the frequency at which flows exceed the top of banks and activate the floodplain is highly variable in Reach 1 based on the degree of channel entrenchment and presence of flood control infrastructure including levees.

Table 4-8. Channel cross-section dimensions for R1XS1 and R1XS2 in Reach 1.

Metric	R1XS1	R1XS2
Floodprone Width (ft)	551.1	228.5
Bankfull Width (ft)	38.7	51.0
Entrenchment Ratio	14.2	4.5

Table 4-8. Channel cross-section dimensions for R1XS1 and R1XS2 in Reach 1.

Metric	R1XS1	R1XS2
Mean Depth (ft)	5.3	6.0
Maximum Depth (ft)	8.0	8.0
Width/Depth Ratio	7.4	8.5
Bankfull Area (sq ft)	203.8	307.7
Wetted Perimeter (ft)	48.5	55.9
Hydraulic Radius (ft)	4.2	5.5

Bedforms in Reach 1 of the Calapooia River consist primarily of elongated riffles with marginal pools formed on the outside of meander bends and at hydraulic constriction points formed by large wood (Figure 4-16). The profile encompasses approximately 650 ft and includes channel thalweg, water surface, bankfull, and terrace elevations. Bedforms are homogenous and lack pool-riffle sequences that are typically present in undisturbed rivers exhibiting pool-riffle morphology similar to the Calapooia River. Pool habitat features were extremely limited in the Reach 1. Channel profile gradients for Reach 1 are presented in Table 4-9.

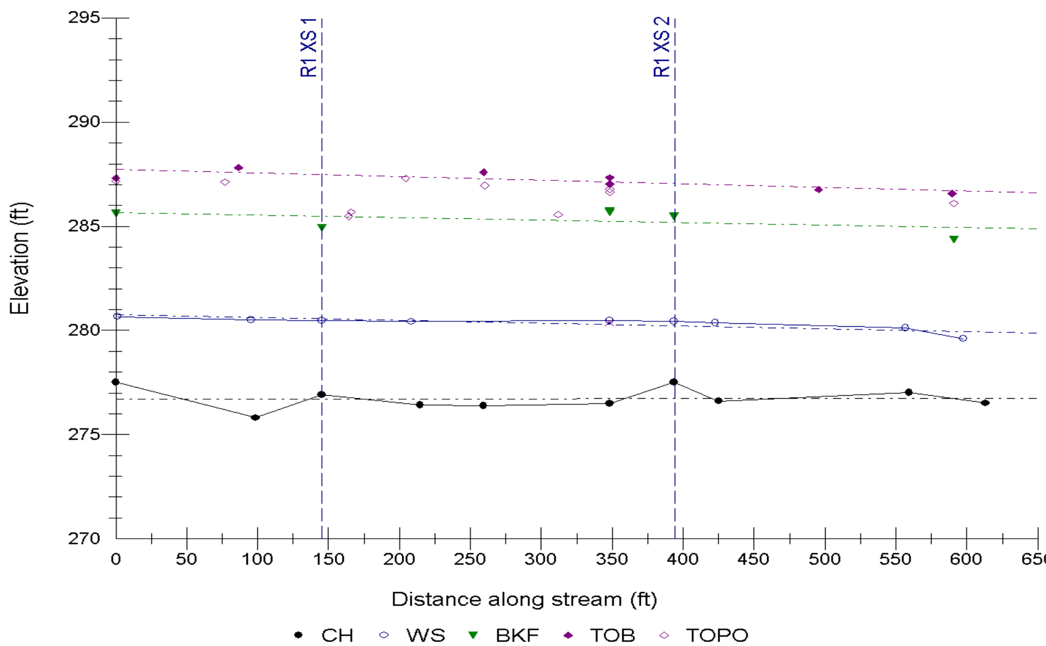

Figure 4-16. The longitudinal channel profile for Reach 1 showing the location of cross sections R1XS1 and R1XS2. Profile points include the channel thalweg, water surface, bankfull feature, top of bank, and other topographic points.

Table 4-9. Reach 1 longitudinal channel profile slope values.

Metric	Value
Top of Bank/Terrace Slope (ft/ft)	0.00173
Bankfull Slope (ft/ft)	0.00125
Water Surface Slope (ft/ft)	0.00142
Channel Thalweg Slope (ft/ft)	0.00161

Hydraulic Modeling Results

Based on the modeled split flow flood frequency analysis completed by TetraTech (2008) and RDG surveyed cross-sections, the Calapooia River's floodplain is inundated on an annual basis. However, based on field observation, the frequency at which flows exceed the top of banks and activate the floodplain is highly variable in the reach based on the degree of channel entrenchment and presence of flood control infrastructure. Due to the split flows, 22 percent to 32 percent of the total flow enters the Calapooia River channel at the bifurcation during periods when discharge is less than 1,500 cfs (less than a 1-year recurrence interval discharge. Based on modeled hydraulic results for Reach 1, the bankfull channel capacity and full channel capacity in Reach 1 is approximately 750 cfs and 1,300 cfs, respectively. The 2-year discharge in the Calapooia River downstream of the bifurcation is 1,576 cfs. Therefore, bankfull channel indicators (e.g. slope break) suggest the channel has about half of the necessary capacity to convey the 2-year event. Flows exceeding 750 cfs would inundate the adjacent floodplain surfaces causing localized flooding.

Table 4-10. Channel hydraulics for the Calapooia River's channel capacity at R1XS1 and R1XS2 in Reach 1. Based on hydraulic modeling at the Calapooia River bifurcation, the 2-year discharge for the Calapooia River channel is 1,576 cfs (TetraTech 2008). The bankfull channel in Reach 1 has the capacity to convey less than half the 2-year event. Including the adjacent floodplain, the river can convey approximately 1,250 cfs.

	R1XS1	R1XS2		
Metric	Channel Capacity	Observed Condition	Bankfull Channel	Channel Capacity
Discharge (cfs)	1,287	65	750	1,250
Flow Area (ft^2)	397	82	250	362
Velocity (ft/sec)	3.2	0.8	3.0	3.5
Wetted Width (ft)	56.3	37.7	46.0	55.0
Hydraulic Depth (ft)	7.1	2.2	5.4	6.6
Shear Stress (lb/ft^2)	0.40	0.17	0.38	0.46

Land Use

Agriculture is the dominant land use in the reach, with grass seed the primary crop. Agricultural fields bracket the river corridor, either interacting with the river or bordering the riparian zone. Floodplain levees are common along portions of upper Reach 1, typically located where there is minimal riparian buffer between the active channel and farmed areas. A floodplain berm is located on the northeast floodplain from the entrance to the Calapooia River downstream approximately 2,500 ft. The berm consists of earthen fill and rock and is situated parallel to agricultural fields. Installation of rip rap and bank armoring has occurred in discrete locations along the channel.

Infrastructure

The Interstate-5 bridge is the primary infrastructure in Reach 1and is the downstream terminus of the reach. Constructed in the 1950s, the bridge appears to have sufficient hydraulic capacity to convey the predicted flood series of the Calapooia River. During construction, two meander sequences upstream of the bridge were truncated to improve the alignment of the channel and bridge inlet.

4.2.2. Reach 2 - The Interstate-5 Bridge to Shear Dam

Reach Overview

Reach 2 of the Calapooia River spans 3.71 miles from the Interstate-5 bridge downstream to Shear Dam. Similar to Reach 1, the altered flow and sediment regimes have facilitated vegetation encroachment on the main channel, increasing channel roughness. These alterations have encouraged a diffuse flow system and in some locations, the channel is non-discernable even during moderate to high flow conditions (e.g. downstream of the I-5 bridge). A reduction in the channel's hydraulic capacity due to blockages caused by large wood, vegetation encroachment, and sedimentation, related to the backwater created by Shear Dam and Thompson's Mills, appears to be increasing the flood hazard risk associated with properties upstream and downstream of Linn West Road. River corridor infrastructure is common in Reach 2, including the Interestate-5 bridge, Linn West Road, private bridges, Roberts Road Bridge No. 12556, floodplain residences, and Shear Dam. Thompson's Mills Dam represents the downstream terminus of Reach 2.

In general, the width of the riparian zone in Reach 2 is narrower than in Reach 1. The Reach 2 riparian corridor is structurally simple and less diverse relative to Reach 1. The riparian canopy forms a narrow ribbon between the active channel and the adjacent uplands that are largely managed for agriculture. The river's proximity to agricultural fields and the reduced channel capacity suggest increased flood hazards, particularly in the vicinity of Linn West Road.

River management, agricultural and residential floodplain development, and vegetation encroachment affect channel conditions. Bank erosion is limited in the reach largely due to vegetation coverage and low stream energy. The riparian vegetation community includes both native and introduced plant species. Native plants include willows, cottonwoods, Oregon ash, red osier dogwood, and alder. Dominant introduced species include Himalayan blackberry and reed canarygrass. Several residential properties have displaced native vegetation in favor of lawns.

A review of times series air photos found that the river has been relatively dynamic in Reach 2 compared to the other reaches in the project area. Most of the channel changes appear to have occurred since the 1956 air photo series. Channel avulsions have resulted in a straighter channel pattern. Infrastructure for water delivery to Thompson's Mills has decreased stream power in Reach 2, leading to channel aggradation and increased flooding potential. Future management changes that would increase flows in the Calapooia River would need to address aggradational trends in the reach.

Channel and Floodplain Morphology

The channel morphology in Reach 2 is characterized by a silt-clay dominated, plane bed stream types. Representative channel cross-sections and one longitudinal profile were completed to characterized existing conditions. The channel and floodplain morphologies and riparian vegetation communities reflect the altered streamflow and sediment regimes. Compared to Reach 1, channel cross-sectional area is decreased by approximately 15 percent due to the extensive channel blockages, diffuse flow patterns, and vegetation encroachment on the active channel. Figure 4-17 and Table 4-11 include typical channel cross-sections in Reach 2 and summary bankfull channel metrics. Entrenchment ratios ranged from 4.3 to 9.5, indicating a high degree of channel-floodplain connectivity for the prevailing streamflow regime. Ground photos capturing example river corridor conditions in Reach 2 are presented in Figure 4-18.

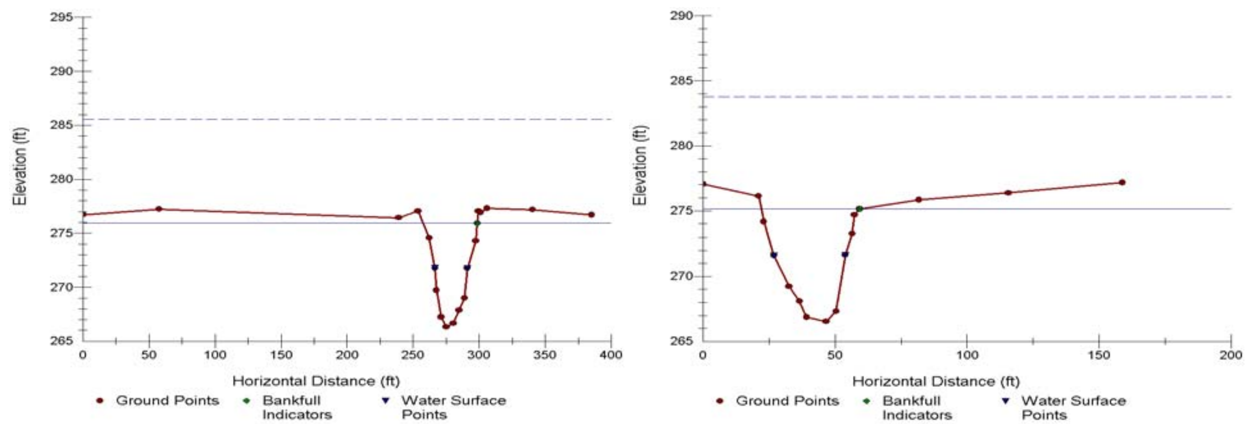

Figure 4-17. Typical channel cross-sections in Reach 2. R2XS3 (left) is located at STA 1+30 and R2XS4 (right) is located at STA 3+25 on the Reach 2 longitudinal profile.

Figure 4-18. Typical channel conditions (left) and an example of a floodplain residence (right) in Reach 2. The riparian corridor includes native species, invasive vegetation, agricultural fields, and residential landscaping.

Table 4-11. Channel cross-section dimensions for R2XS3 and R2XS4 in Reach 2.

Metric	R2XS3	R1XS4
Floodprone Width (ft)	385.1	158.8
Bankfull Width (ft)	41.0	37.3
Entrenchment Ratio	9.5	4.3
Mean Depth (ft)	5.7	5.5
Maximum Depth (ft)	9.6	8.6
Width/Depth Ratio	7.2	6.8
Bankfull Area (sq ft)	233.3	204.0
Wetted Perimeter (ft)	47.2	42.8
Hydraulic Radius (ft)	4.9	4.8

Bedforms in Reach 2 of the Calapooia River consisted primarily of homogenous, extended riffle and run features. Due to vegetation encroachment and the diffuse flow network, pools were limited and primarily filled with fine sediment. Figure 4-19 includes a representative longitudinal profile in Reach 2. The profile encompasses approximately 1,000 ft of channel and reflects thalweg, water surface, bankfull and top of bank features. Average thalweg, water surface and bankfull slopes in the project reach were 0.00236 ft/ft, 0.00045 ft/ft and 0.00049 ft/ft, respectively (Table 4-12). Channel velocities averaged 2.0 fps for both observed and modeled bankfull discharge.

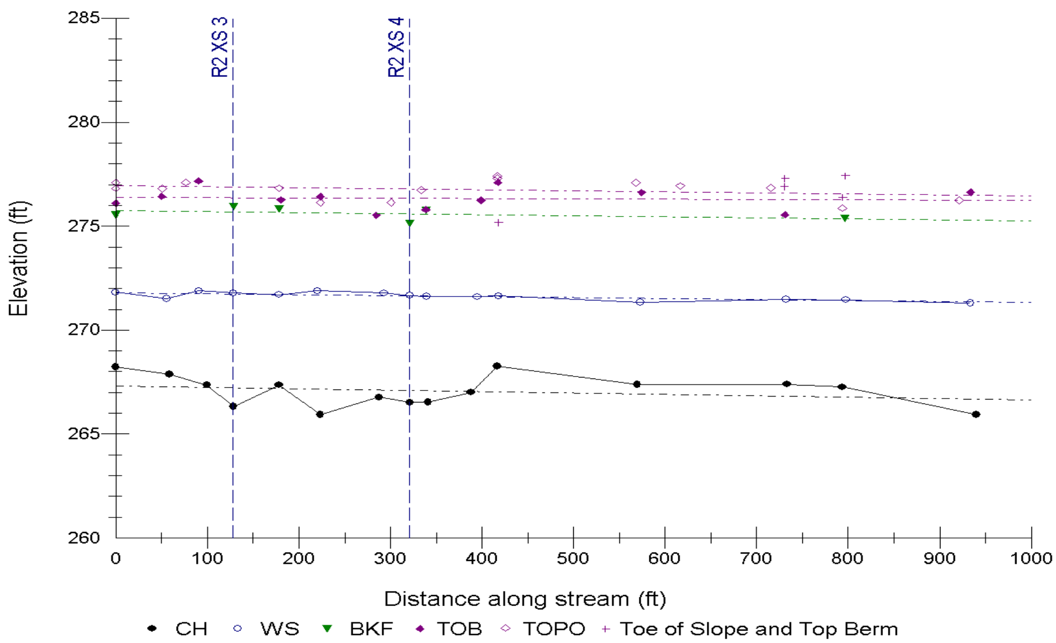

Figure 4-19. The longitudinal channel profile for Reach 2 showing the location of cross sections R2XS3 and R2XS4. Profile points include the channel thalweg, water surface, bankfull feature, top of bank, and other topographic points.

Table 4-12. Reach 2 longitudinal channel profile slope values.

Metric	Value
Top of Bank/Terrace Slope (ft/ft)	0.00013
Bankfull Slope (ft/ft)	0.00049
Water Surface Slope (ft/ft)	0.00045
Channel Thalweg Slope (ft/ft)	0.00236

Hydraulic Modeling Results

Channel hydraulic capacity is limited in the modeled section of Reach 2 due to channel aggradation related to the Thompson's Mills backwater, increased roughness due to vegetation encroachment on the channel, and channel blockages. Similar to portions of Reach 1, the altered flow regime has promoted colonization of vegetation in the active bankfull channel. Inset floodplain features are dominated by reed canarygrass which precludes establishment of native riparian shrubs including cottonwood and willow. Vegetated surfaces within the active channel allude to the lower energy environment, altered sediment transport characteristics, and modified flow regime.

Table 4-13 summarizes channel hydraulic conditions for Reach 2 of the Calapooia River. Based on the modeled flow distribution model developed by TetraTech (2008) at the bifurcation and RDG surveyed cross-sections, the floodplain is inundated at a slightly greater than 1-year return interval discharge. Bankfull channel capacity is 600 cfs with

Table 4-13. Channel hydraulics for the Calapooia River's channel capacity at R2XS3 and R2XS4 in Reach 2. Based on hydraulic modeling at the Calapooia River bifurcation, the 2-year discharge for the Calapooia River channel is 1,576 cfs (TetraTech 2008). The bankfull channel in Reach 1 has the capacity to convey less than half the 2-year event.

	R2XS3	R2XS4		
Metric	Channel Capacity	Observed Condition	Bankfull Channel	Channel Capacity
Discharge (cfs)	600	89	550	600
Flow Area (ft^2)	363	97	279	300
Velocity (ft/sec)	2.0	0.9	1.97	2.04
Wetted Width (ft)	150.6	24.3	46	66
Hydraulic Depth (ft)	7.2	4.0	6.1	4.5
Shear Stress (lb/ft^2)	0.39	0.08	0.4	0.44

Land Use

Agriculture is the dominant land use in the reach, with grass seed the primary crop. Agricultural fields bracket the river corridor, either interacting with the river or bordering the riparian zone. Land use encroachment on the river corridor is more common in Reach 2 than in Reach 1. A majority of the riparian vegetation downstream of the Interstate-5 bridge has been removed or converted to introduced species or lawn and garden cover types. Bank armoring and floodplain levees were present along numerous portions of the reach. Bank armoring was comprised of 6 inch angular rock.

Infrastructure

Floodplain infrastructure is concentrated in Reach 2. Infrastructure includes the Interestate-5 bridge, Linn West Road Bridge No. 12551, the Judith Harrison bridge, Roberts Road Bridge No. 12556, and Shear Dam. In addition, numerous residences are located within the floodplain and appear to be located within the flood hazard area. Modifications to the current streamflow regime would increase the risk of flooding to numerous residents along Reach 2. The following sub-sections provide descriptions of the major infrastructure in Reach 2.

Linn West Road Bridge No. 12551 (Linn County)

Linn West Road consists of a 130 ft concrete span bridge with wooden crib abutment walls (Figure 4-20). Four sets of piers support the bridge and are located between the ordinary high water marks of the river. Each set of piers contains approximately six to eight treated piles measuring 12 inches to 18 inches in diameter. Bridge freeboard relative to the bankfull channel indicators was estimated to at 3.5 ft. The piers obstruct flow at the entrance to the bridge and exacerbate helical scour around the piers. Small diameter wood was accumulated on the piers and obstructs flow.

The measured bankfull width upstream of the bridge was 42 ft. Based on a span width of 130 ft, the bridge likely provides adequate hydraulic capacity for the modeled flood series of the Calapooia River. Recent filling of the right floodplain surface was observed during the field reconnaissance.

Figure 4-20. Linn West Road Bridge No. 12551 is located in the upper section of Reach 2 near the intersection Linn West Road and Roberts Road. The bridge is supported by four wooden piers that obstruct flow and reduce the hydraulic capacity of the bridge inlet.

Based on existing bridge attributes, the bridge appears to be adequately sized for the prevailing streamflow regime, although flows of large magnitude may impart backwater conditions upstream of the bridge inlet, exacerbating flood hazard risk. A more detailed bridge analysis is recommended if proposed restoration alternatives increase streamflow in the Calapooia River.

Harrison Bridge (Private)

The Judith Harrison Bridge is located approximately 1.5 miles downstream of the Linn West Road Bridge and 0.5 miles upstream of Roberts Road Bridge No. 12556. The bridge consists of concrete abutments and stringers and spans the bankfull channel width of the Calapooia River (Figure 4-21). The bridge appears to have limited capacity to convey large floods. The upstream channel width measured 48 ft. The bridge span measured only 36 ft resulting in a bridge constriction ratio of 0.75. The floodplain is blocked by the bridge approach grades. Bridge freeboard, measured from the low chord elevation to the estimated bankfull water surface elevation was 2.5 ft. During the field survey, the water surface was within 2.0 ft of the bridge deck.

Figure 4-21. The Harrison Bridge is constructed of concrete decking and abutments. Based on the measured span, freeboard, and bankfull channel width upstream of the bridge, the structure is significantly undersized and would need further evaluation if alternatives to increase streamflow to the Calapooia River are considered.

Roberts Road Bridge No. 12556 (Linn County)

Roberts Road Bridge No. 12556 crosses the Calapooia River approximately 0.5 miles upstream of Shear Dam and the inlet to the Thompson's Mills millrace. The bridge spans 70 ft and consists of a concrete deck, steel piers and abutments (Figure 4-22). The bridge is supported by a pier consisting of six steel piles located in the center of the channel cross-section. The channel width upstream of the bridge is 40 ft, for an approximate bridge constriction ratio of 1.75. Bridge freeboard, measured from the low chord elevation to the estimated bankfull channel elevation, was 5.0 ft.

Figure 4-22. Roberts Road Bridge No. 12556 consists of a concrete deck, steel piers and abutments. The bridge provides adequate span for the existing streamflow regime. Hydraulic analyses would be required if future alternatives consider increasing streamflows to the Calapooia River.

Similar to the Interstate-5 bridge in Reach 1, the Calapooia River appears to have been channelized upstream of the bridge inlet. Several meander oxbows were observed on the southwest floodplain surface. The oxbows provide marginal wetland habitat and agricultural land uses have converted a majority of the forested riparian corridor to non-wetland and riparian plant communities.

Shear Dam

Shear Dam is located at the end of Reach 2 and is approximately 2.1 miles upstream of the Thompson's Mills State Heritage Site. The dam was constructed to divert streamflow from the Calapooia River into a constructed millrace that delivers water to Thompson's Mills. The dam is retrofitted with a 6 ft concrete pool and weir fish ladder consisting of three steps spaced at 8 ft intervals. The upstream step has a two foot notch to concentrate low flow and provide suitable depths for fish passage. The dam is constructed of concrete with a crest width of 40 ft.

Figure 4-23 includes photographs of Shear Dam and the pool and weir fish ladder. While a detailed model of the existing dam was not completed to evaluate fish passage capabilities, it is presumed that the structure is a partial fish passage barrier for certain life histories stages of fish.


Figure 4-23. Existing condition photos of Shear Dam (left) and associated pool and weir fish ladder. Hydraulic conditions likely impede fish passage during certain flow stags.

Shear Dam represents the downstream extent of Reach 2 in the study area. The dam also denotes a significant change in the geomorphology and landforms of the Calapooia River.

4.2.3. Reach 3 - Shear Dam to the Thompson's Mills State Heritage Site

Reach Overview

Reach 3 spans 2.23 miles from Shear Dam to the Thompson's Mills raceway where diverted flows rejoin the Calapooia River. Shear Dam, located downstream of the millrace bifurcation that sends water to Thompson's Mills, controls the Calapooia River's water surface elevation upstream of the dam. Depending on how the dam's flashboards are managed, both facilities can create a substantial backwater on the Calapooia River. Figure 4-24 illustrates the influence of Shear Dam and Thompson's Mills on water surface elevations in the millrace channel. Other infrastructure in Reach 3 includes the Boston Mill Drive Bridge No. 12287A.

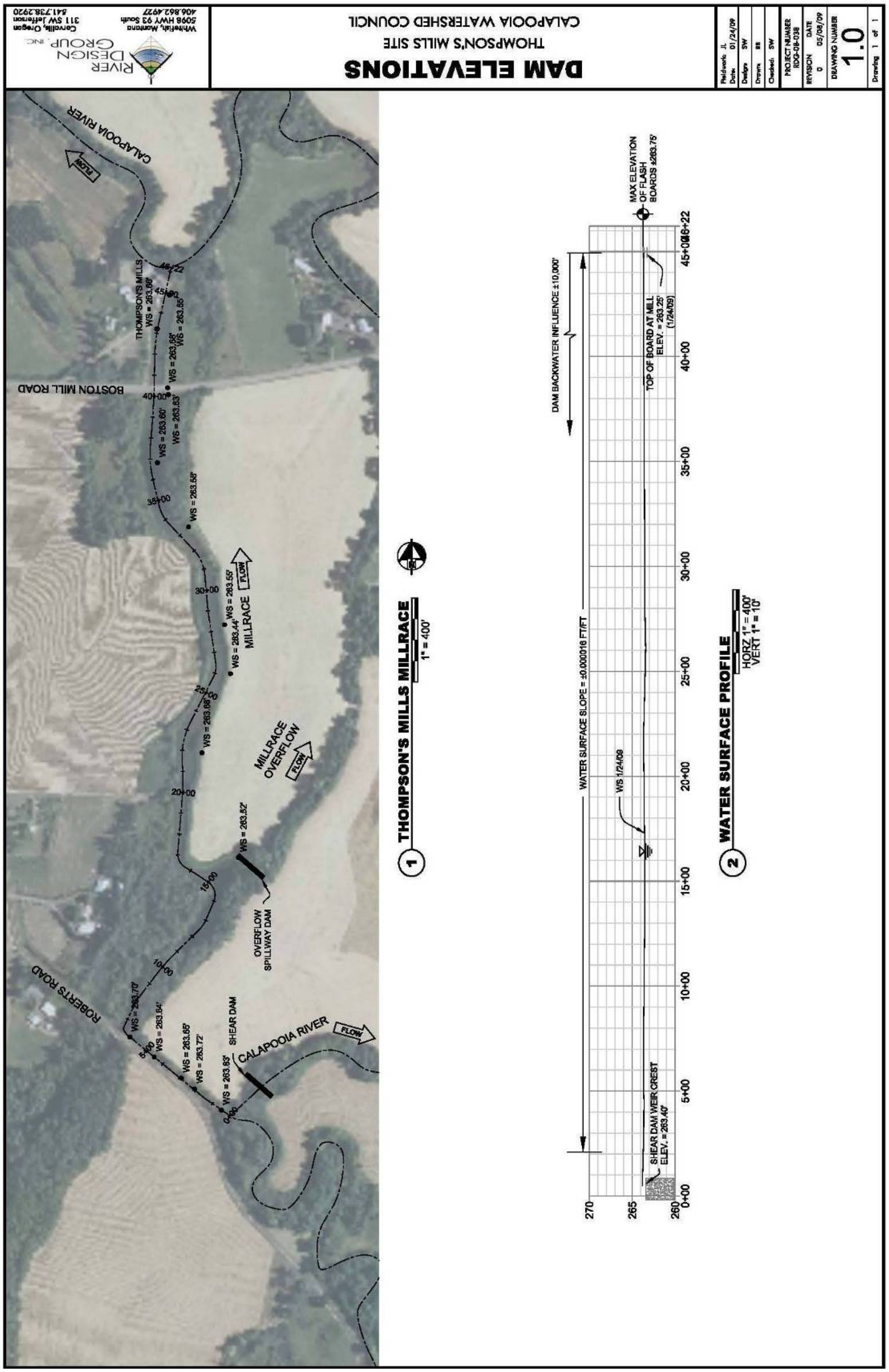

Figure 4-24. The Thompson's Mills millrace from Shear Dam to Thompson's Mills. The Mills has the potential to backwater over 10,000 ft of the Calapooia River.

The Calapooia River downstream of Shear Dam has eroded 8 ft to 15 ft into the valley bottom. The river corridor is "gorge" like in appearance with near-vertical, well-vegetated sideslopes transitioning from the main valley floor and agricultural fields down to the bankfull channel. The channel is substantially more defined in Reach 3 than it is in Reach 2, suggesting the influence of the backwater effect created by Thompson's Mills spillway and Shear Dam on the Calapooia River in Reach 2. The backwater effect reduces stream energy resulting in a depositional regime and decreased channel capacity. Conversely, the channel in Reach 3 is characterized by a silt-clay bed with gravel lenses, a channel width ranging from 30 ft to 40 ft, and well-vegetated steep but stable streambanks. Increasing slope, channel confinement, and lower width to depth channel ratios result in a more competent and complex riverine system in Reach 3 compared to upstream reaches.

Riparian vegetation in Reach 3 is similar to the riparian community in Reach 2. Vegetation forms a narrow buffer between the river and adjacent agricultural lands. Most of the historical riparian corridor has been converted to agricultural land in Reach 3. Bank erosion was limited in the reach due to the presence of deep-rooted vegetation colonizing the near-vertical sideslopes and narrow inset floodplain surfaces bordering the main channel. The riparian vegetation community includes both native and introduced plant species. Native plants include willows, cottonwoods, Oregon ash, red osier dogwood, and alder. Dominant introduced species include Himalayan blackberry and reed canarygrass. Several residential properties have displaced native vegetation in favor of lawns.

A review of times series air photos revealed fairly consistent channel conditions in Reach 3. The channel has been in several positions within the narrow belt width since the 1936 air photo. However, channel locations have been within a narrow range, suggesting the channel incision may control lateral channel migration. Primary areas of channel adjustment are limited to two areas with a slightly broader riparian zone.

Geomorphic Conditions

The channel morphology in Reach 3 is characterized by entrenched to slightly entrenched, silt-clay dominated, plane bed stream types. Representative channel cross-sections and one longitudinal profile were completed to characterized existing conditions. The channel is entrenched in the valley bottom. The river corridor is simplified due to the channel incision. Side channels and floodplain features are lacking as indicated in the typical cross-sections in Figure 4-25. Table 4-14 includes summary bankfull channel metrics. Ground photos capturing example river corridor conditions in Reach 3 are presented in Figure 4-26.

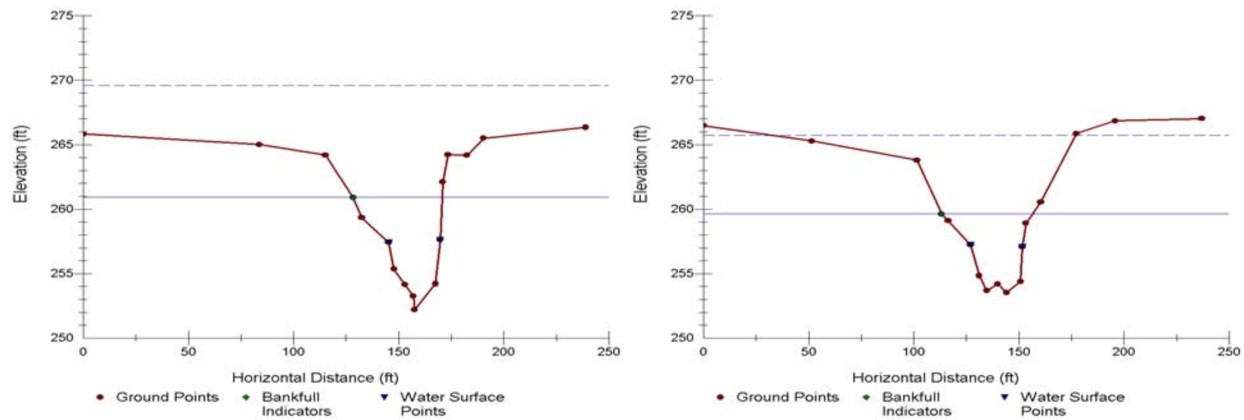

Figure 4-25. Typical channel cross-sections in Reach 3. R3XS5 (left) is located at STA 2+60 and R3XS6 (right) is located at STA 4+25 on the Reach 3 longitudinal profile.

Figure 4-26. The Calapooia River in Reach 3 including a view downstream of Shear Dam (left) and an example vertical eroding bank with poor riparian vegetation coverage (right).

Table 4-14. Channel cross-section dimensions for R3XS5 and R3XS6 in Reach 3.

Metric	R3XS3	R3XS6
Floodprone Width (ft)	238.9	143.9
Bankfull Width (ft)	42.3	43.1
Entrenchment Ratio	5.6	3.3
Mean Depth (ft)	4.8	3.5
Maximum Depth (ft)	8.7	6.1
Width/Depth Ratio	8.9	12.5
Bankfull Area (sq ft)	202.1	149.0
Wetted Perimeter (ft)	48.8	47.2
Hydraulic Radius (ft)	4.1	3.2

Bedforms in Reach 3 of the Calapooia River consisted primarily of homogenous, extended riffle and run features. Riffle habitat dominated the survey reach. Figure 4-27 includes a representative longitudinal profile in Reach 3. The profile encompasses approximately 700 ft of channel and reflects thalweg, water surface, bankfull and top of bank features. Average thalweg, water surface and bankfull slopes are included in Table 4-15.

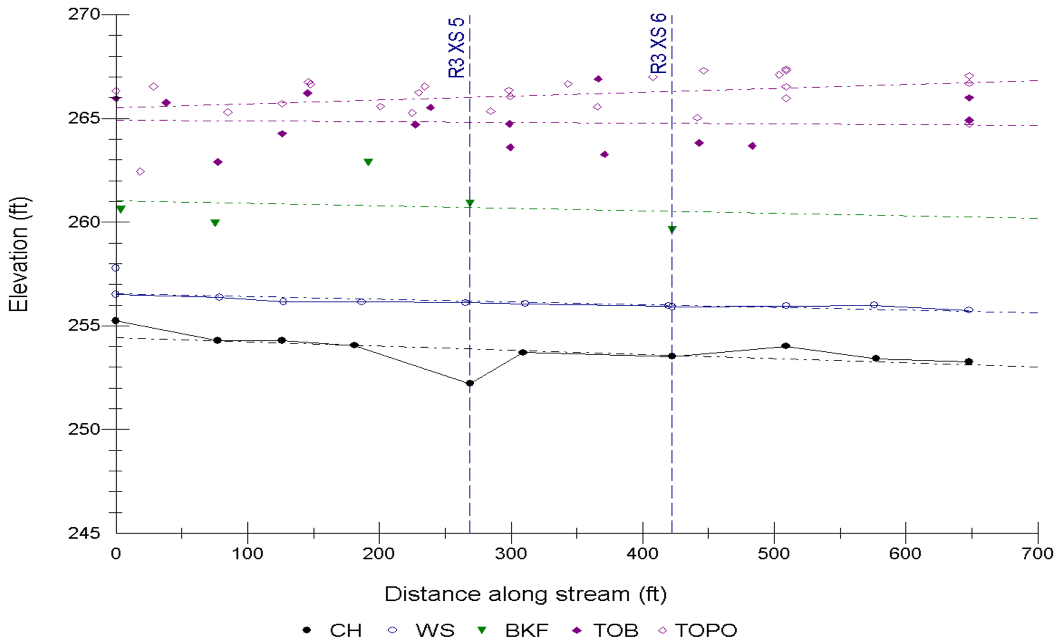

Figure 4-27. The longitudinal channel profile for Reach 3 showing the location of cross sections R3XS5 and R2XS6. Profile points include the channel thalweg, water surface, bankfull feature, top of bank, and other topographic points.

Table 4-15. Reach 3 longitudinal channel profile slope values.

Metric	Value
Top of Bank/Terrace Slope (ft/ft)	0.00037
Bankfull Slope (ft/ft)	0.00115
Water Surface Slope (ft/ft)	0.00136
Channel Thalweg Slope (ft/ft)	0.00307

Hydraulic Modeling Results

Channel hydraulics were calculated for both cross-sections in Reach 3 (Table 4-16). Channel hydraulic capacity is limited in the modeled section of Reach 3 due to the low channel gradient and undersized cross-sectional area. The undersized cross-sectional area is related to the spit flows at the Shear Dam bifurcation. A portion of the flow is routed to the Thompson's Mills millrace, while the remaining discharge flows down the Calapooia River channel. This split flow has also resulted in decreased channel capacity in the Calapooia River. Additional modeling will be necessary to determine the flow split at Shear Dam.

Based on the modeled flow distribution model developed by TetraTech (2008) at the bifurcation and RDG surveyed cross-sections, the Calapooia River bankfull channel has the capacity to convey slightly more than half of the 2-year event. Again, the Calapooia River channel has also responded to the split flow condition at the Shear Dam bifurcation by decreasing the cross-sectional channel area.

Table 4-16. Channel hydraulics for the Calapooia River's channel capacity at R3XS5 and R3XS6 in Reach 3. Based on hydraulic modeling at the Calapooia River bifurcation, the 2-year discharge for the Calapooia River channel is 1,576 cfs (TetraTech 2008). The bankfull channel in Reach 3 has the capacity to convey less than half the 2-year event.

	R3XS5	R3XS6		
Metric	Bankfull Channel	Observed Condition	Bankfull Channel	Channel Capacity
Discharge (cfs)	800	65	800	1,600
Flow Area (ft^2)	360	81.6	394	739
Velocity (ft/sec)	2.22	0.8	2.03	2.52
Wetted Width (ft)	58	37.7	70	191
Hydraulic Depth (ft)	6.2	2.2	5.7	7.8
Shear Stress (lb/ft^2)	0.39	0.12	0.33	0.45

Land Use

Agriculture is the dominant land use in the reach, with grass seed the primary crop. Agricultural fields bracket the river corridor, either interacting with the river or bordering the riparian zone. The native riparian zone has been narrowed over time by agricultural production. Shear Dam, the Spillway Dam, Thompson's Mills, and Boston Mill Road comprise the infrastructure within the reach.

Infrastructure

Primary infrastructure in Reach 3 includes the Boston Mill Drive Bridge No. 12287A and the Thompson's Mills State Heritage Site mill and spillway. Boston Mill Drive Bridge No. 12287A consists of a125 ft span concrete deck with steel stringers and abutments. Four sets of pier support the bridge; two sets are located below the ordinary high water mark and two are set within the active floodplain. The upstream bankfull channel width measured 40 ft for a bridge constriction ratio of approximately 3.0. Based on the measured freeboard (20 ft from low chord to bankfull elevation), the bridge appears to have adequate capacity to convey the existing flow regime without adversely impacting channel morphology.

Thompson's Mills spillway enters the Calapooia River at the downstream terminus of Reach 3. The spillway flashboards can regulate up to 16 ft of elevation on the Calapooia River. Figure 4-28 includes existing condition photographs of the Thompson's Mills spillway and mill, and the confluence of the Calapooia River and Sodom Ditch.

Figure 4-28. The Thompson's Mills spillway and mill denote the downstream terminus of Reach 3. The left photo shows the spillway from the spillway confluence with the Calapooia River. The right photo includes the confluence of the spillway and the Calapooia River and the start of Reach 4. The right photo was taken standing next to the spillway shown in the left photo.

4.2.4. Reach 4 - Thompson's Mill Spillway Return to Butte Creek

Reach Overview

Reach 4 of the Calapooia River assessment area extends 2.5 miles from Thompson's Mills to the Butte Creek confluence. The river in Reach 4 exhibits channel morphologies ranging from a simplified cross-section to dynamic river conditions exemplified by off-channel habitats and a broader inset floodplain. The river maintains a sinuous channel pattern downstream of Thompson's Mills. Although the channel location has remained within a narrow range since the 1936 air photo series, two side channels that were apparent in the 1956 and 1967 air photos appear to now be disconnected from the channel alignment. Thompson's Mills is the primary infrastructure in the reach. One residential property is located near the Calapooia River's confluence with Butte Creek at the end of the reach.

The Calapooia River has eroded 8 ft to 15 ft deep into the valley floor in Reach 4. The channel in Reach 4 is characterized by a silt-clay bed and streambanks and channel widths ranging from 30 ft to 65 ft. Streambanks are well-vegetated with steep but stable side slopes. An inset well-vegetated floodplain is developing within the over-widened, entrenched channel, perhaps indicating a new equilibrium for the river. Several oxbow meanders/terraces located 5 ft to 15 ft above the current channel base elevation, represent at least two former floodplain surfaces. The current channel's elevation relative to these higher surfaces suggests there have been two periods of channel incision and equilibrium.

The riparian zone in Reach 4 is similar to the riparian community in Reach 1 with a wider riparian community than in Reach 2 and Reach 3. The broader riparian zone may be related to the sinuous channel pattern and the effort that would be necessary to clear more of the riparian zone for agriculture.

Large wood and vegetation encroachment in Reach 4 is common, creating diverse flow paths and habitat. Bank erosion is limited in the reach largely due to vegetation coverage and low stream energy. The riparian vegetation community includes both native and introduced plant species.

Native plants include willows, cottonwoods, Oregon ash, red osier dogwood, and alder. Introduced species include Himalayan blackberry and reed canarygrass although these species are not as dominant as they are in other reaches.

A review of times series air photos revealed fairly consistent channel conditions in Reach 4 over time. Similar to the other reaches, the riparian corridor has been narrowed for agricultural production. Agriculture is the dominant land use in the reach, with grass seed the primary crop. Agricultural fields bracket the river corridor, either interacting with the river or bordering the riparian zone.

Geomorphic Conditions

The channel morphology in Reach 3 is characterized by silt-clay dominated, plane bed stream type. Representative channel cross-sections and one longitudinal profile were completed to characterized existing conditions (Figure 4-29). The river corridor maintains a diverse riparian zone and large wood provides aquatic habitat diversity. Floodplain channels and wetlands suggest an active channel history. Ground photos capturing example river corridor conditions in Reach 4 are presented in Figure 4-30. Table 4-17 includes summary bankfull channel metrics.

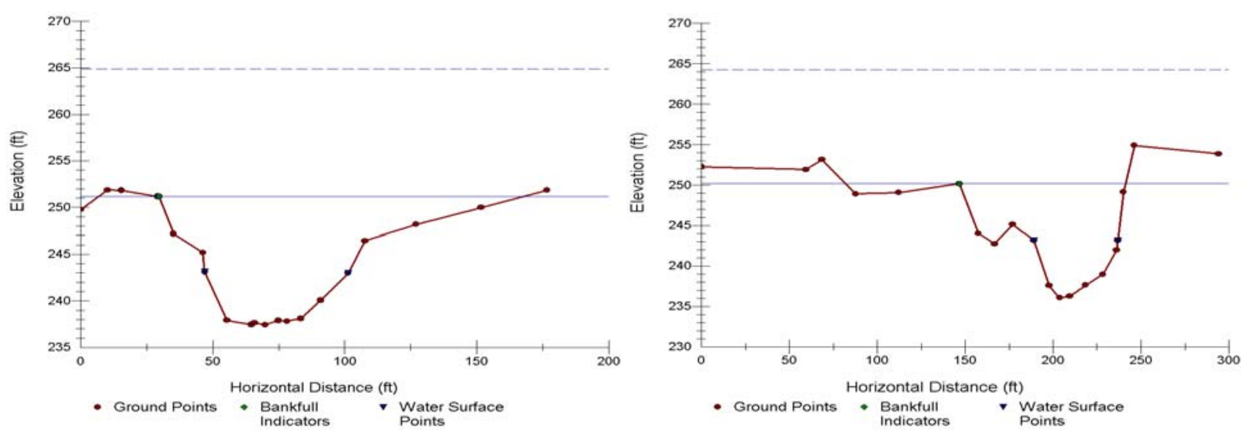

Figure 4-29. Typical channel cross-sections in Reach 4. R4XS7 (left) is located at STA 2+60 and R4XS8 (right) is located at STA 4+25 on the Reach 4 longitudinal profile.

Figure 4-30. Typical channel conditions in Reach 4 (left) and an example large wood array (right).

Table 4-17. Channel cross-section dimensions for R4XS7 and R4XS8 in Reach 4.

Metric	R4XS7	R4XS8
Floodprone Width (ft)	176.5	294.1
Bankfull Width (ft)	145.4	159.3
Entrenchment Ratio	1.2	1.9
Mean Depth (ft)	6.3	5.4
Maximum Depth (ft)	13.7	14.1
Width/Depth Ratio	23.3	29.4
Bankfull Area (sq ft)	909.3	862.1
Wetted Perimeter (ft)	153.1	168.9
Hydraulic Radius (ft)	5.9	5.1

The channel profile in Reach 4 was limited by vegetation conditions and water depth. A water surface profile was completed in order to develop the cross-section hydraulics for R4XS7 and R4XS8. (Figure 4-31)

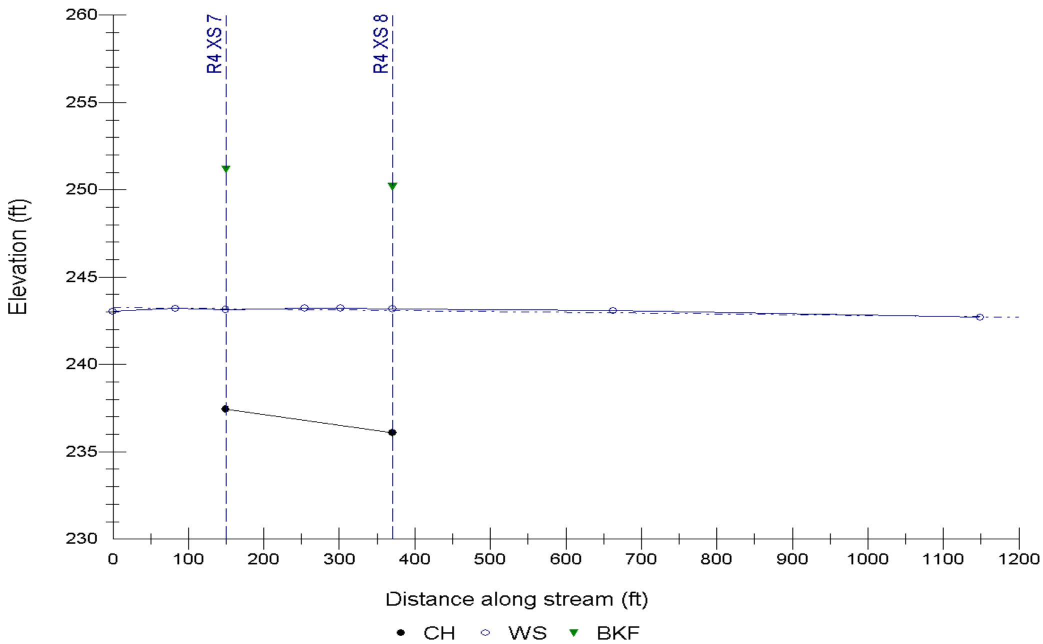

Figure 4-31. The longitudinal channel profile for Reach 4 showing the location of cross sections R4XS7 and R4XS8. Profile points include the channel thalweg, water surface, bankfull feature, top of bank, and other topographic points. The Reach 4 water surface slope was 0.00043.

Hydraulic Modeling Results

The Reach 4 cross-sections are located downstream of the confluence of the Thompson's Mills millrace and the Calapooia River. Below the confluence, the bankfull channel capacity doubles relative to Reach 3. The bankfull channel is capable of conveying between a 2-year and 5-year event based on the modified flood frequency at the Calapooia River-Sodom Ditch bifurcation. Similar to the other modeled cross-sections, average bankfull velocities were approximately 3 fps (Table 4-18).

Table 4-18. Channel hydraulics for the Calapooia River's channel capacity at R4XS7 and R4XS8 in Reach 4. Based on hydraulic modeling at the Calapooia River bifurcation, the 2-year discharge for the Calapooia River channel is 1,576 cfs (TetraTech 2008). The bankfull channel in Reach 4 has the capacity to convey between the 2-year event and the 5-year event.

	R4XS7	R4XS8		
Metric	Bankfull Channel	Observed Condition	Bankfull Channel	Channel Capacity
Discharge (cfs)	2,100	89	2,100	2,750
Flow Area (ft^2)	745	79.4	801	1,066
Velocity (ft/sec)	3.15	1.1	2.92	3.13
Wetted Width (ft)	119	35.7	126	193.3
Hydraulic Depth (ft)	6.3	2.2	6.4	5.5
Shear Stress (lb/ft^2)	0.65	0.13	0.72	0.79

Land Use

Agriculture is the dominant land use in the reach, with grass seed the primary crop. Agricultural fields bracket the river corridor, either interacting with the river or bordering the riparian zone. The native riparian zone has been narrowed over time by agricultural production. Thompson's Mills and Wirth Road comprise the infrastructure within the reach.

Infrastructure

Primary infrastructure in Reach 4 includes the Thompson's Mills State Heritage Site mill and spillway. The Wirth Road crossing is downstream of the Calapooia River confluence with Butte Creek and was not included in the survey.

4.3. Sodom Ditch Review

4.4. Summary

The Calapooia River Geomorphic Assessment included remote sensing, field data collection, and hydraulic modeling to evaluate conditions on the Calapooia River. The effort assessed historical and current conditions pertaining to river morphology, riparian vegetation, land use, and infrastructure. Historical channel analysis dating back to 1936 shows that the Calapooia River has experienced typical river processes including meander cutoffs, down-valley meander migration, and avulsions. It appears that the transition of dominant flow from the Calapooia River to Sodom Ditch has altered natural river processes in the Calapooia River and created a more stable river with very few changes in the last 15 years. Additionally, the redistribution of flow by Shear Dam and Spillway Dam, and the backwater effect caused by Thompson's Mills, has resulted in atypical river morphologies. River management has resulted in lower flows and a less dynamic river environment. The more static conditions have allowed vegetation to encroach on the channel and stabilize depositional features within and adjacent to the baseflow channel. This process in addition to the routing of flows to facilitate Thompson's Mills operation, has lead to the reduction in channel cross-sectional area from Reach 1 through Reach 3. The convergence of flows from the Thompson's Mills millrace and the Calapooia River, increases the channel capacity to the extent that the cross-sectional area is capable of conveying between the 2-year and 5-year flood event. Additional hydraulic modeling with a more complete data set will be necessary to verify this result.

Based on the assembled information and observed trends, it is likely that these geomorphic and vegetation trends will continue as Sodom Ditch continues to capture more flow and the Calapooia River continues to aggrade. Subsequent phases of this project will further evaluate river hydraulics in the project area to provide a better understanding of channel capacity and actions that would be necessary to re-establish the Calapooia River as the primary channel in the project area. In consideration of future planning efforts, the following reach-specific issues should be addressed.

Reach 1

Reach 1 was characterized by a silt-clay dominated, plane bed river. The modified flow and sediment regimes have reduced the Calapooia River's channel capacity in Reach 1. Reduced channel capacity is a limiting factor for future restoration actions. The following issues should be considered when planning future restoration actions in Reach 1.

- Restoring all flows to Reach 1 would require extensive floodplain and channel excavation to increase hydraulic capacity and increase sediment transport competency and capacity.
- Maintaining a split flow condition at the bifurcation will continue to mandate regular intervention and maintenance following moderate to high flow conditions due to sediment and debris deposition in the bifurcation area.
- Land uses adjacent to the channel have displaced native riparian vegetation communities along portions of the reach. Altered riparian conditions have exacerbated bank erosion conditions at numerous locations. Restoration actions would need to include structural bank stabilization measures and extensive floodplain revegetation, particularly along the southern floodplain/terrace surface. Expanding the riparian corridor will be necessary for long-term bank stability and habitat.
- There is minimal floodplain infrastructure in Reach 1. Therefore, restoration alternatives that increase flows to the Calapooia River in Reach 1 may be feasible as there would be limited infrastructure effects.
- A detailed hydraulic analysis would be required for the Interstate-5 bridge if increasing flows is considered a restoration component as it appears to be undersized.
- The existing floodplain berms would need to be evaluated to determine the effects on flood hazard risk and prevailing land uses with an increase in discharge in the Calapooia River.

Reach 2

Reach 2 of the Calapooia River is a depositional reach due to the backwater created by Thompson's Mills and Shear Dam. The altered flow and sediment regimes have facilitated vegetation encroachment on the main channel, encouraging a diffuse flow system. A reduction in the channel's hydraulic capacity due to blockages caused by large wood, vegetation, and sediment, appears to be increasing the flood hazard risk associated with properties upstream and downstream of Linn West Road. Floodplain infrastructure is most concentrated in Reach 2 compared to the other reaches.

The following issues should be considered when planning future restoration actions in Reach 2.

- Restoring all flows to Reach 2 would require extensive excavation of the floodplain and channel to increase hydraulic capacity and increase sediment transport competency and capacity.
- Significant floodplain infrastructure, such as residential homes and bridges, occurs in Reach 2 with a significant concentration of homes around Linn West Road. Restoration alternatives that increase flows to the Calapooia River may not be feasible without

relocating residences and replacing bridges. Options for relocating structures outside of the river's floodplain would need to be considered.

- A detailed hydraulic analysis would be required for all bridges in Reach 2.
- The effects of Shear Dam and Thompson's Mills dam operations need to be further quantified. The results of this assessment indicate that the backwater effect extends approximately 10,000 ft upstream of Thompson's Mills, altering the channel geometry and sediment transport characteristics in Reach 2.

Reach 3

The Calapooia River in Reach 3 is characterized by a silt-clay bed with gravel lenses, and well vegetated, silt-clay streambanks. The river channel in Reach 3 has adjusted to the split flow conditions created by Shear Dam and Spillway Dam. The channel cross-sectional area is approximately half as large in Reach 3 compared to Reach 4 downstream from the millrace and Calapooia River confluence. The surface water diversion necessary to route water to Thompson's Mills has resulted in a decreased channel capacity of the Calapooia River between Shear Dam and the start of Reach 4. However, compared to Reach 2, Reach 3 is more characterized by an increasing slope, greater channel confinement, and a lower width to depth ratio channel.

The following issues should be considered when planning future restoration actions in Reach 3.

- The river channel is more stable in Reach 3 than upstream reaches in the study area
- The river has responded to the Shear Dam diversion by channel area adjustment. The channel cross-section is approximately half of the Reach 4 cross-sectional area
- Restoring all flows to Reach 3 would require extensive excavation of the floodplain and channel to increase hydraulic capacity and increase sediment transport competency and capacity.
- Options for retrofitting Shear Dam to reduce backwater effects and improve fish passage should be considered with any restoration alternative.
- Modifying Thompson's Mills dam operations should be considered to reduce backwater effects and altered hydraulic and sediment transport characteristics upstream of the facility in Reach 2 and Reach 3.
- Floodplain infrastructure is minimal in Reach 3 and should not pose significant constraints on restoration opportunities in the reach. Additional routing of flows in Reach 3 may require protective measures for Thompson's Mills.

Reach 4

Reach 4 is characterized by an entrenched channel downstream from Shear Dam. The river maintains a sinuous channel pattern and portions of the reach display reference channel and aquatic habitat conditions compared to upstream reaches. Aquatic habitat and hydraulic conditions are more complex and dynamic in Reach 4, attesting to the positive influence of the combined river flows downstream of the millrace and Calapooia River confluence.

The following issues should be considered when planning future restoration actions in Reach 4.

- Compared to upstream reaches, Reach 4 is more stable and complex with high-quality aquatic habitat and a multi-story riparian corridor.
- Portions of the reach should be further measured and characterized to provide an example of typical reach conditions that could be supported on the Calapooia River in a split flow regime.
- Floodplain infrastructure is minimal in Reach 4 and should not pose significant constraints to restoration opportunities in the reach.

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APPENDIX A
REACH MAPS

APPENDIX B
GEOLOGY, SOILS, AND VEGETATION MAPS

APPENDIX C
HISTORICAL CHANNEL ANALYSIS MAPS

APPENDIX D
GEOMORPHIC DATA

APPENDIX E
PHOTO LIBRARY