Restoring the Salmon River Estuary

Journey and Lessons Learned Along the Way 2006 - 2014

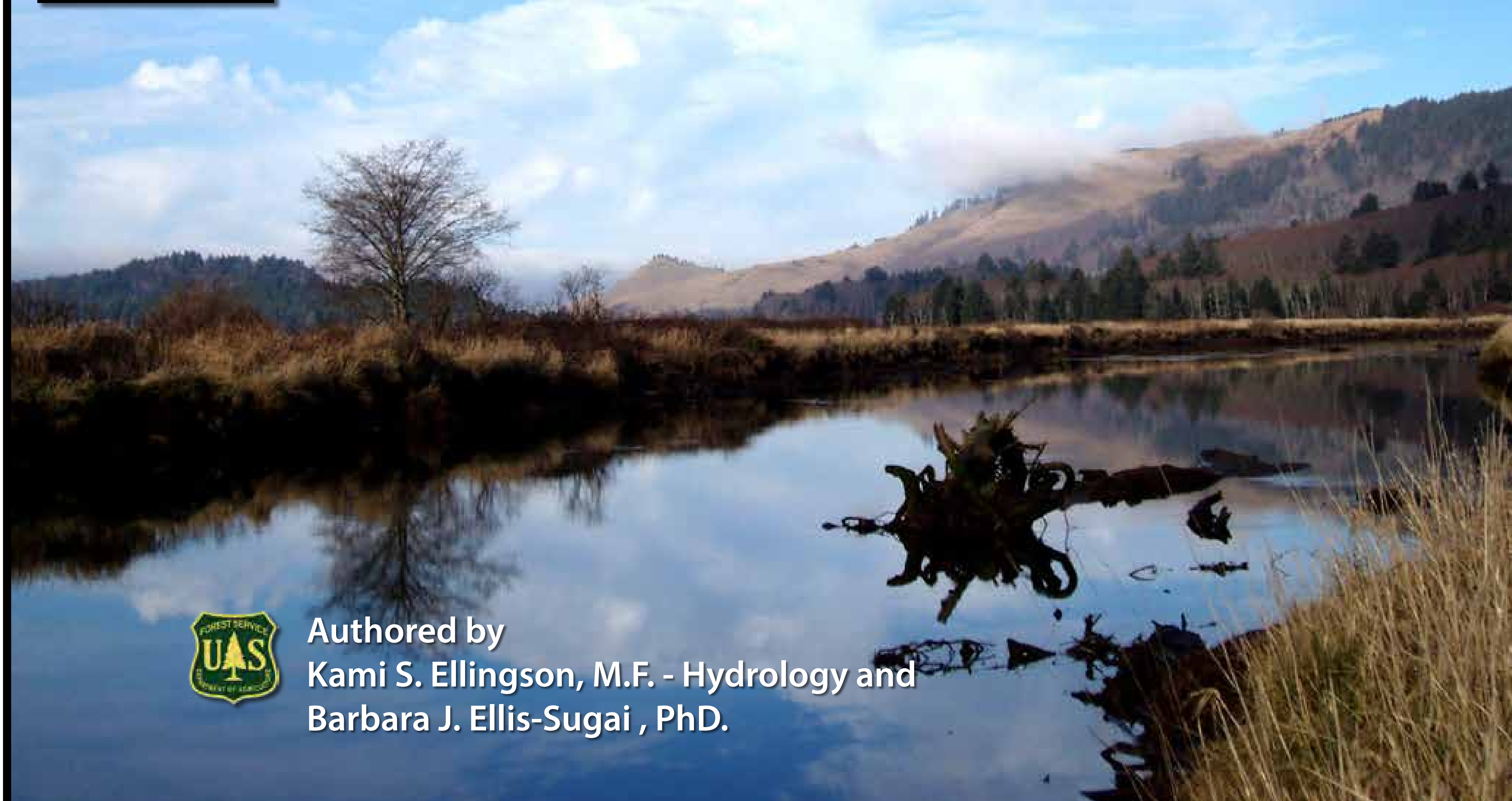

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Figure 1. *2012 aerial photo of the Salmon River estuary. January 1, 2005. Photo credit Duncan Berry.*

Acknowledgments:

Contributors: Doug Glavich, Cindy McCain, Catherine Pruett and Jason Wilcox

Special thanks to the Siuslaw National Forest Hebo District employees.

We would also like to sincerely thank a community of people and organizations for their technical, logistical, moral and financial support of this project. A list of partners and contributors is on page 46.

Cover Photo Barbara Ellis-Sugai

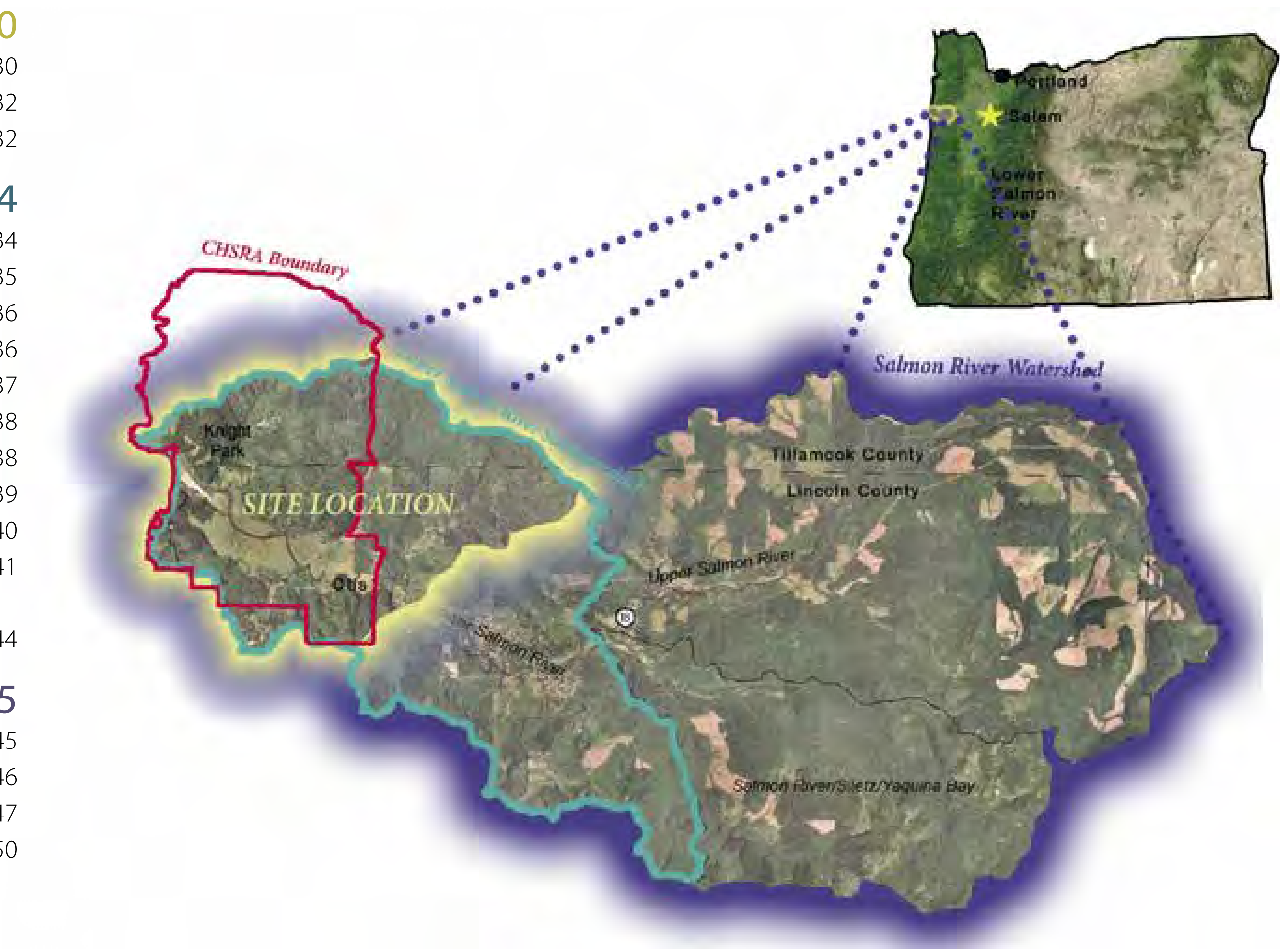
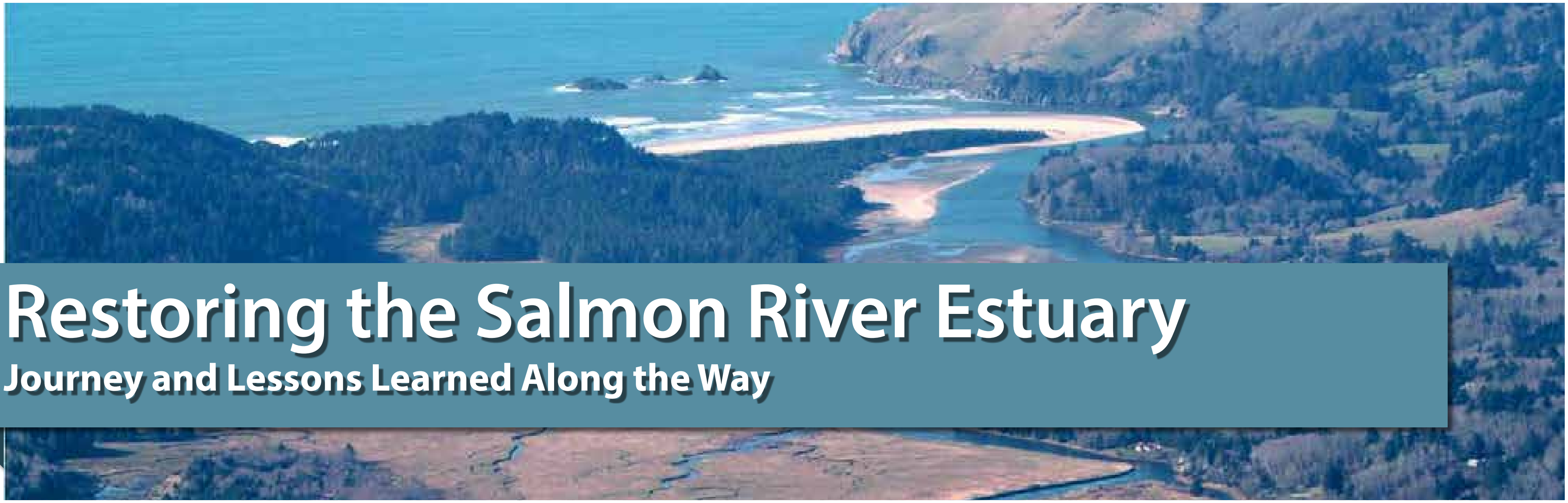


Figure 2. *Site Location Map. The Salmon River meets the Pacific Ocean on the central Oregon Coast, approximately four miles north of Lincoln City. The area encompasses 16.1 square miles in the western portion of the 75 square mile Salmon River watershed, straddling Lincoln and Tillamook Counties.*



Restoring the Salmon River Estuary

Journey and Lessons Learned Along the Way

Cascade Head Scenic-Research Area, 1974

"…to provide present and future generations with the use and enjoyment of certain ocean headlands, rivers, streams, estuaries and forested areas, to ensure the protection, the study of a significant area for research and scientific purposes, and to promote a more sensitive relationship between people and their adjacent environment…"

Introduction

This report was created for natural resource professionals involved in the art and science of ecological restoration, as well as members of the general public interested in the restoration efforts in the Salmon River estuary. While ecological restoration has been in progress since the late 1970s, the focus of this document is the more recent efforts which began in 2006.

The goal of this report is threefold. First, we want to provide a brief history of the human use and interest in the area. This eventually led to the passage of the 1974 Cascade Head Scenic-Research Area Act and recognition of the ecological value of this landscape. Secondly, this report provides a summary of the restoration efforts between 1978 and 1996. Finally, we wanted to provide an in-depth review of the most recent restoration projects happening in the area, beginning with a student-led analysis and planning charrette during the summer of 2006. In this document, our goal is to share what we learned about executing large-scale, complex restoration projects, what worked well and what could have worked better.

Historic Overview of the Salmon River Estuary

The Salmon River estuary is one of the few remaining relatively undeveloped estuaries on the Oregon Coast, despite its long history of human use. Archaeological evidence has found Native American village sites, as early as 1020 AD, near the mouth of the Salmon River[1]. The people in these communities ate salmon as a primary food source, lived in plank slab houses, used dugout canoes and excelled at basketry[2].

In November 1855, an executive order issued by President Franklin Pierce created the Siletz Oregon Coast Reservation. The executive order set aside the land bordered by Cape Lookout on the north to the Siltcoos River on the south, and east to the crest of the Coast Range including the area around Cascade Head and the Salmon River estuary. It encompassed the territories of the Siuslaw, Alsea, Yaquina, Siletz, Salmon River and Nestucca Indians. As early as 1865, however, under pressure from white settlers, another executive order was signed by President Andrew Johnson that opened a portion of the Siletz Reservation to white settlement. It included a tract of land from Yaquina Bay south to the northern side of the Alsea River estuary. In 1875 Congress passed an act that "restored" parts of the Siletz Reservation to the public domain. It opened up all the lands to settlement between Yaquina Bay and the Siltcoos River, as well as all lands between the mouth of the Salmon River and Cape Lookout. By then, the much reduced Siletz Reservation included the area between the Coast Range and the Pacific Ocean, from the mouth of the Salmon River to a point two miles south of the Siletz Agency headquarters.

Settlers soon began locating homesteads in the lower Salmon River[3]. Initially there were only a few white families within the Cascade Head-Salmon River estuary area. They engaged in subsistence living and depended on cattle grazing, hunting, fishing and raising vegetables. The number of homesteaders within the Cascade Head Scenic-Research Area boundaries increased between 1895 and 1910, primarily due to the Dawes Severalty Act of 1887. This act allotted individual parcels of land to Native Americans of the Siletz Reservation. In 1895 all land not allotted to these individuals was opened to settlement. As allotments became vacant, white settlers filed claims for these properties.

Figure 3. *1975, oblique aerial photo of the Salmon River estuary.*

A *1978 dike removal*

B *1987 dike and tide gate removal*

C *1996 dike and tide gate removal*

D *2008-2009 removal of the Tamara Quays trailer park development and Rowdy Creek marsh restoration*

E *Former Pixieland Amusement Park site (estuary restoration 2010-2011)*

F *Reference marsh*

G *Cascade Head*

1 (Ross, 1990, in Zobel, 2002)
2 (Beckham, 1975)
3 (Beckham, 1975)

In 1923 the section of the Coast Highway (Old Highway 101) between the Salmon River and Neskowin was built. The Salmon River Highway (Highway 18) was paved in 1930. As transportation improvements opened up the area, farmers turned to dairy farming. The area also became more accessible to tourist traffic and vacation visitors.

In 1938 the YWCA of Portland, Oregon acquired 380 acres south of the mouth of the Salmon River to construct a camp, which became Camp Westwind.

Between 1954 and 1974 most of the estuary had been diked and ditched to create pastures. *(Figure 3)*. The majority of the dike building occurred in the early 1960s[4]. U.S. Highway 101 originally meandered through the Cascade Head Experimental Forest west of Salmon Creek and Neskowin (Slab) Creek. In 1961 it was rerouted into a shorter and straighter route across the estuary. It was built with one bridge across the Salmon River and no culverts or bridges where the new highway crossed Salmon and Fraser Creeks. Instead, these two creeks were rerouted into ditches adjacent to the highway. The stream channels downstream and northwest of the highway became dead-end sloughs. The highway roadbed across the estuary is nine feet higher than the estuary surface. As a result, the highway functions as a large dike. It cuts the estuary into two ecologically separate parts, constricting the flow of the tides and the river. The aerial photo taken in 1961 *(Figure 4)* shows the highway under construction.

In 1965 Jerry Parks of Lincoln City purchased 57 acres at the Highway 18 and U.S. Highway 101 junction intending to build a recreation park tentatively called Pioneer Town. It eventually became Pixieland, a short-lived amusement park *(Figure 3)*.

Ecologically, several changes occurred including the construction of the ditches and dikes, the installation of tide gates and the construction of U.S. Highway 101. When marshes are diked and cut off from tidal flow and sediment input, they will subside over time as organicly-rich soils oxidize. In the Salmon River estuary[5], measured marsh surface elevations were 35 cm (1.13 feet) lower in the diked marshes as compared to the adjacent controls[6]. Tidal channels were cut off by tide gates and made inaccessible to migrating fish. Sediment deposition patterns across marsh surfaces were altered. By the early 1960s, 75% of the lower Salmon River marsh habitat was isolated by dikes and tide gates and had been converted to pasture.[7] In 1974 Congress passed the Cascade Head Scenic-Research Area Act (Public Law 93-535), which created the Cascade Head Scenic-Research Area (CHSRA). The CHSRA was divided into subareas. The estuary and associated wetlands subarea was designated as "area managed to protect and perpetuate the fish and wildlife, scenic and research-education values, while allowing dispersed recreation use, such as sport fishing, non-motorized pleasure boating, waterfowl hunting and other uses which the Secretary determines are compatible with the protection and perpetuation of the unique natural values of the subarea. *After appropriate study, breaching of the existing dikes may be permitted within the subarea*." (Italics added.) (Public Law 93-535). The boundaries of the CHSRA are shown in *Figure 2*.

In 1976 the accompanying Final Environmental Statement for the Management Plan was written for the CHSRA. "It establishes a long-term goal of restoring the Salmon River estuary and its associated wetlands to a natural estuarine system free from man's developments."[8] Over time most of the tidally influenced land in the estuary has been transferred to U.S. Forest Service ownership.

Public Law 93-535 and the associated management plan set the stage and provided the mandates for restoring the Salmon River estuary.

Figure 4. *1961 Aerial photo. U.S. Highway 101 under construction.*

The Ecological Importance of the Salmon River Estuary

Estuaries are important nurseries for young salmon. Recent research[9] has found 95% of Chinook salmon spend significant amounts of time in estuaries. Research done in 2000-2002 in the Salmon River estuary found Chinook salmon fry disperse into the estuary in the early spring and many move into restored tidal marsh habitat. They move out into the ocean in early fall after an extended period of time in the estuary *(Figure 5)*. "The absence of fry migrants in the estuary during spring and early summer in 1975-1977, a period that precedes restoration of any of the diked marshes and the extensive use of marsh habitats by fry and fingerlings in April-July in 2000-2002, indicate that wetland restoration has increased estuarine rearing opportunities for juvenile Chinook salmon."[10] The tidal marshes and tributaries support Chinook, coho *(Figure 6)*, steelhead and cutthroat trout.

In the past, salmon were abundant enough to support a family-owned cannery. At the present time coho salmon are severely depressed in the Salmon River Basin. Within the Salmon River estuary, habitat losses from dikes around marshes, loss of off-channel habitat and a decrease in water quality have contributed to the salmon species' decline. The Oregon Department of Fish and Wildlife (ODFW) estimates current coho numbers are just 10% of what they were in the past.

The Salmon River Hatchery was built in 1975. It produced fall Chinook, coho and summer steelhead. In the last 10 years only Chinook and coho have been produced. Due to the recent declines in wild coho populations, hatchery release of coho was discontinued in 2006. The elimination of hatchery coho production presents an opportunity to return the Salmon River watershed to a wild coho river system.

In 1976 the Cascade Head Scenic-Research Area was also recognized by the United Nations as a Biosphere Reserve.

Figure 5. *Salmonid life cycle. Research indicates that salmon fry are spending more time in the estuary than first believed.*

Figure 6. *Coho salmon fry.*

Figure 6

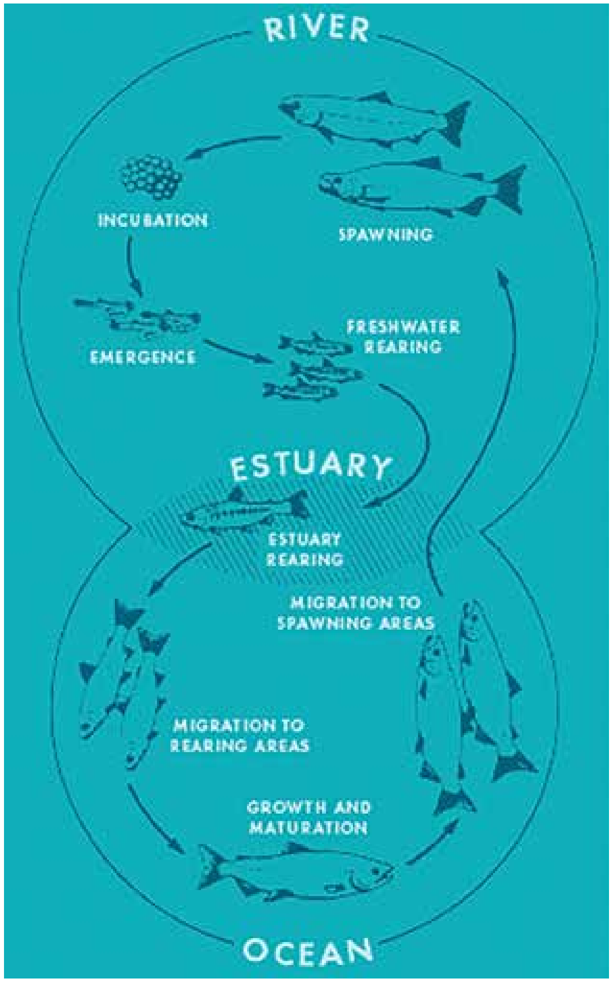


Figure 5

4 (Gray, 2005)
5 (Frenkel and Morlan, 1991)
6 (Gray, 2005)
7(Frenkel and Morlan, 1991)
8 (USDA-FS FEIS, page ii, 1976)
9 (Jones, et al, 2014)
10 (Bottom, et al, 2005)

Restoration Work Prior to 2006

Estuary restoration work began in 1978 with the partial removal of dikes north of the Salmon River that surrounded 52 acres. The dike material that was removed was used to fill barrow ditches where the dike's fill material was obtained.[11] The restoration of this marsh area became the subject of a doctoral dissertation by Diane Mitchell (1981) and this area is informally known as the Mitchell Marsh. *Figure 7* shows the projects (referred to by years completed) as they existed in a 1975 aerial photo. *Figure 8* shows the same areas after restoration in 2012. In 1987 the dikes and tide gate enclosing a large marsh area south of the Salmon River, and west of the reference marsh, were removed. This area is referred to as the "Y" marsh due to its proximity to the YWCA camp. At the same time the remaining dike material in the Mitchell Marsh was leveled to the historic marsh elevation.

In 1996 the dike on the east bank of the Salmon River and north of U.S. Highway 101 was removed. The tide gate on Salmon Creek was also removed. The purpose of this project was to restore wetlands on Forest Service property. To protect private property to the east of the Salmon Creek Marsh, the project included plans to build an earthen berm with a tide gate on the property line. Due to difficulties getting the appropriate permits from the regulatory agencies, and Oregon Department of Transportation's concern about the dike construction next to U.S. Highway 101, material could not be imported for the berm. Instead, on-site native material had to be used. Two ditches were dug on either side of the berm to obtain the fill material. The marsh soils were poorly suited for berm construction and the berm eventually failed. It was repaired twice between 1996 and 2007. The private land on the other side of the berm was persistently wet during the winter, partly as a result of the failed berm and partly because the diked pasture had subsided over time. As a result, the pasture land changed from grasses to rushes and other wetland vegetation.

One of the lesson learned from this project was that it would have been better to delay the project until consensus was reached with all parties so a more robust berm could have been built. The success of a project should not be compromised in order to meet budget constraints or timelines. A solution to the problems of the failing berm and subsiding ground was considered as part of the planning process in the post-2006 work. It was never implemented due to differences between the regulatory requirements and the landowner's wishes.

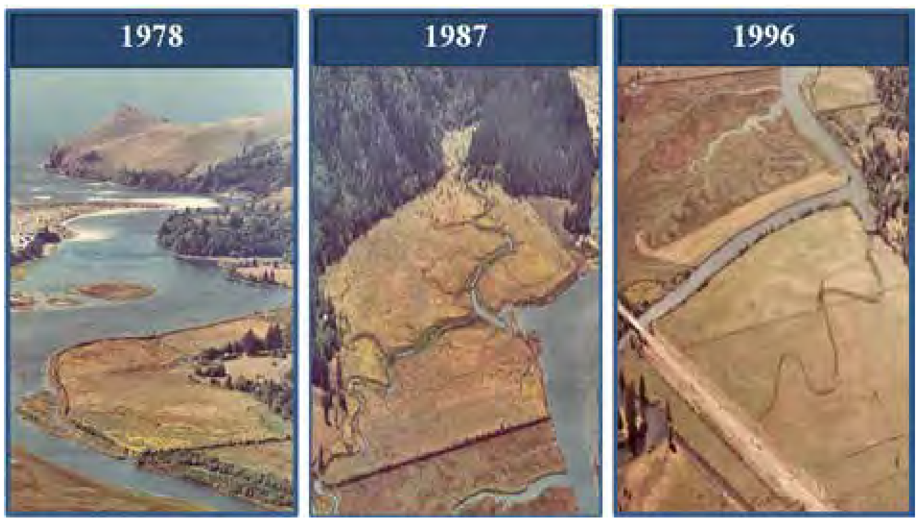


Figure 7: *1975 aerial view of the low marsh land in the estuary prior to restoration. (Dates above photos indicate the year restoration occurred.)*

Figure 8: *2012 aerial view of the low marsh land in the estuary after restoration. (Dates above photos indicate the year restoration occurred.)*

Site-Specific Projects Summary

Name	Description	Issues	Recommendations
1. Pixieland	Former cannery, pulp mill and the Pixieland amusement park; vacant for nearly three decades	Severely altered hydrology and concentrations of invasive species throughout the site	Reconnect Fraser Creek, remove dikes, ditches, and ponds; invasive species control; remove asphalt; open parking and river access
2. Tamara Quays	Former farm and mobile home park; vacant since 2004	Severely altered hydrology and concentrations of invasive species throughout the site	Remove dikes; restore Rowdy Creek; invasive species control; remove concrete; construct a trail on the terrace
3. U.S. Highway 101	The Oregon coast highway functions as a dike	Severely altered hydrology and concentrations of invasive species along the shoulder	Construct a viaduct from Three Rocks Road to Fraser Road, reconnecting Salmon and Fraser Creeks
4. Waterways	The main stem of the Salmon River, its tributaries and tidal channels	Fish passage culverts, channel complexity, water quality and riparian buffers are limited	Encourage replacement of culverts, enhancement and restoration of riparian buffers; place wood in streams to enhance pools
5. Three Rocks Road/ Knight Park	Access road to residential areas; Knight Park provides the only public parking, boat launch and restroom facilities	Safety issues associated with cyclists using the road and motorists stopping to view the estuary	Construct a bike lane and wayside overlook point on the Three Rocks Road; replace culverts and remove fill at Knight Park.
6. Dikes and Ditches	Remnants of the area's agricultural heritage remain scattered throughout the site	Altered hydrology and scattered concentrations of invasive species	Prioritize and remove remaining dikes and ditches

Estuary Restoration Work: 2006 to 2014

In the summer of 2006 a team of graduate students participated in an internship to develop a comprehensive restoration plan for the Salmon River estuary[12]. Along with identifying watershed-wide projects like eliminating invasive plant species, they also identified six site-specific, high priority projects. These included:

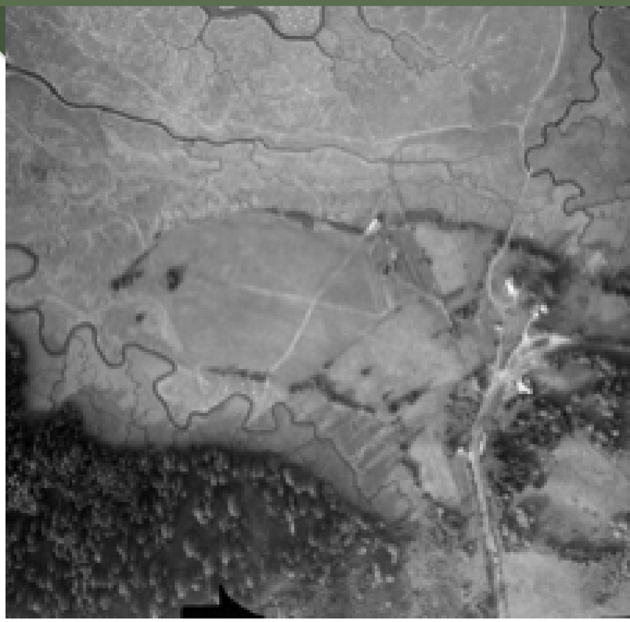
- The restoration of the old Pixieland site;
- Restoring the Tamara Quays trailer park site;
- Dike removal at Crowley Creek;
- Reconfiguring U.S. Highway 101 to reconnect both Fraser and Salmon Creeks; and
- Interpretive sites and trail access.

On-the-ground restoration work began during the summer of 2007 at Tamara Quays and Pixieland. Crowley Creek was restored in 2012 and a marina which was carved into the marsh floor was restored in 2014.

***Figure 9:** Identified project locations.*

11 (Frenkel and Morlan, 1990)
12 (Greer, et al., 2006)

Tamara Quays



BEFORE
1944, Rowdy Creek and future Tamara Quays site. Highway 18 is in the lower right corner.

DURING
1974, Tamara Quays in development.

AFTER
June 2012, Tamara Quays, two years after the restoration.

"…27,500 cubic yards of soil moved in a six-week period, equaling 2,750 dump truck loads."

History & Overview

Construction began at the Tamara Quays trailer park development in 1969 along the head of tide of Rowdy Creek *(Figure 10)*. The area was surrounded by dikes and a dam had been built to separate the development from the rest of the estuary. A tide gate had been installed on Rowdy Creek, both where Rowdy Creek entered and left the development. Kingfisher Lake, a small pond, was dug into a section of Rowdy Creek. The pond was part of the development's landscaping scheme. A septic system and water system using water wells drilled on a hill above the site were installed, roads were paved and small, individual lots were sold.

Tamara Quays had several problems almost immediately. The septic system was built inappropriately for a wetland and came under the scrutiny of the county and state health departments. The water system worked on an intermittent basis and the area almost flooded in February 1996. After the Cascade Head Scenic-Research Area was designated, the Forest Service was given the right to purchase land from willing sellers in the estuary subarea. As people sold their individual lots at Tamara Quays, the Forest Service purchased them. The process of acquiring the entire property was slow and the area was not completely within Forest Service ownership until 2003. *Figures 11* shows a plat map on a bare earth LiDAR image after development.

Figure 10

Planning

We visited the Lincoln County Planning Office and found a wealth of information on the Tamara Quays development including letters describing the proposed development, applications for building permits and "as built" maps showing the location of underground utilities which proved useful in planning the dismantling of the development. However, there were still unknown aspects of the development. For instance, the location of the septic tank wasn't precise and probing was required to locate it. Additionally, when the marsh surface was exhumed, several hundred feet of PVC pipe were exposed that had to be hauled to a disposal site.

The LIDAR mapping from November of 2007 was invaluable in determining the precise existing elevations of the site and providing a base map for the grading plans produced by the project engineer *(Figure 11)*. Detailed AutoCAD drawings allowed for an accurate estimate of the cubic yards that had to be removed and rearranged.

We were fortunate to have an undisturbed marsh surface in the reference marsh next to the site. A total station survey was done to determine the elevation of several locations on this marsh surface. It served as the target elevation for the restoration of the buried marsh surface next to Rowdy Creek.

Air photos taken prior to the development between the 1940s and early 1960s were studied and used to determine the historic tributary stream channel locations, the position of Rowdy Creek prior to the excavation of Kingfisher Lake and slope breaks between the marsh surface and the upland areas.

Figure 11

Figure 10: *1975 Oblique photo of the Tamara Quays development.*
Figure 11: *Plat map on bare earth LiDAR of the Tamara Quays development.*

Figure 12. *The exposed PVC pipe marks the original marsh elevation. Fill removal is in progress in the background.*

Figure 13. *Removing fill from the buried marsh floor. Note the dried grass that was uncovered in the foreground, which confirms the original marsh surface has been uncovered.*

Figure 14. *Removal of the final portion of dike that surrounded the development.*

Figure 15. *After removal of the final portion of the dike.*

Summary:
Work Accomplished at Tamara Quays 2007– 2009

In 2007 the restoration work focused on clearing the site of any remnant infrastructure from the trailer park. This included decommissioning a long-failing septic system and removing concrete trailer pads and asphalt roads. The clean-up work continued in 2008 when it mainly focused on removing underground utilities *(Figure 12)*.

The main project in 2008 was replacing the undersized culvert and removing a tide gate which controlled freshwater entering the site. It also prevented fish movement *(Figure 17)*. The culvert at the head of tide on Rowdy Creek under Fraser Road was replaced with a culvert which allows aquatic organism access to the upper portion of Rowdy Creek *(Figure 18)*. *Figure 19* was taken from the top of the new culvert at Rowdy Creek during a ten foot tide and storm event.

The majority of the restoration work was done in 2009. The marsh surface adjacent to Rowdy Creek was exposed for the first time since the late 1960s and fill material, approximately three feet deep, was removed *(Figure 13)*.

The dikes, dam and lower tide gate were removed. This connected the area to the rest of the estuary *(Figures 14,15 & 20)*. *Figure 21* is a photo just after the tide gate was removed. *Figure 22* depicts the same location three years later with a returning king tide. Ditches were also filled in. In addition to the earthwork, two wells were decommissioned and a power pole and power line were relocated. The restoration crew moved and rearranged 27,500 cubic yards of dirt (*Figures 25 and 26)*. Fill material was removed from the surface of the marsh, all dikes were removed and the tributaries to Rowdy Creek were reconnected. *Figure 16* shows a map of the work. Reestablishing native vegetation and controlling invasive weeds still continues today. See *Figure 27*.

For additional details and photos on the Tamara Quays restoration, see Appendix page 47.

Figure 17

Figure 18

Figure 19

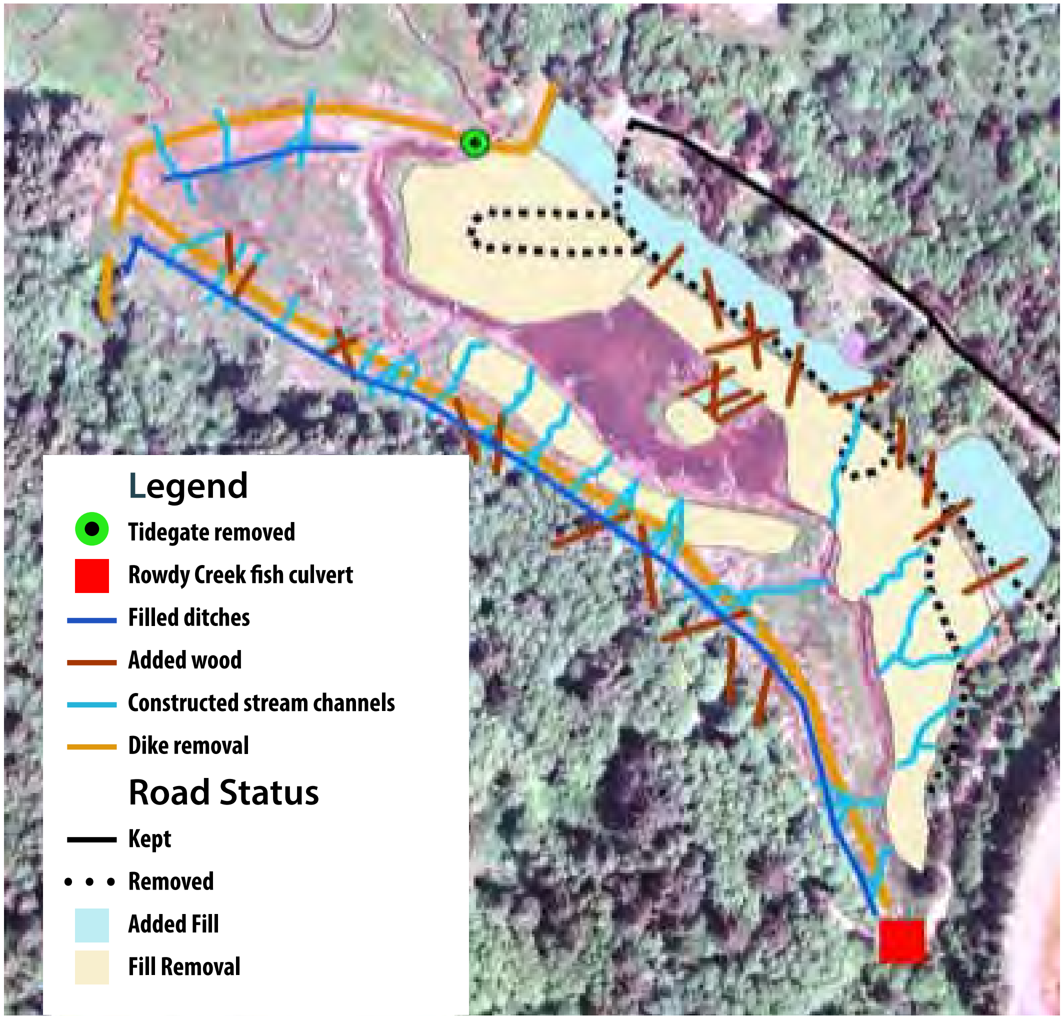


Figure 16

Figure 20

Figure 21

Figure 22

Figure 16. *Annotated air photo taken in June 2012 shows the location of the work done in 2008 and 2009.*

Figure 17. *Upper tide gate on Rowdy Creek. (Red box in Figure A).*

Figure 18. *New open bottom culvert that replaced the tide gate on Rowdy Creek.*

Figure 19. *January 19, 2010. Ten foot tide and rain event flooding the restored marsh.*

Figure 20. *Removing the culvert at the tide gate at the lower end of the development. (Green dot in Figure 16).*

Figure 21. *Rowdy Creek after the lower tide gate has been removed. (Green dot in Figure 16).*

Figure 22. *January 2013 king tide three years after the restoration.*

Lessons Learned at Tamara Quays

Infrastructure removal was a larger part of the project than originally anticipated. It wasn't until the fill was removed that we understood the extent of the infrastructure that had to be removed from the site. This included two dump truck loads of old PVC pipe. The PVC pipe that was removed in 2009 had been laid on the surface of the old marsh and covered with fill. When the fill was removed, the PVC pipe was exhumed and needed to be disposed. None of the underground infrastructure was documented on the "as built" maps for the development.

The water tank *(figure 23)* was welded in place in seven foot sections, measuring 35 feet tall. To decommission it, we had to build a crib downslope to prevent the tank from rolling when it was pulled over. The tank was flattened and recycled.

The septic tank *(Figure 24)* was made of cinder block and measured 12 feet wide, by 26 feet long, by 12 feet deep and was covered with a thin, rusted piece of sheet metal. With equipment standing by, we located the tank by measuring from a known junction box.

Pacific Power moved a power pole from the area that was restored to tidal wetlands and replaced it with two power poles along Fraser Road. The planning process had overlooked the power pole issue. Pacific Power personnel were very cooperative in getting the work done in a timely fashion that met the project's timelines.

The tide gate under the dam had both a slider gate at the inlet and a top-hinged flap valve on the outlet. In 2007 both tide gate mechanisms were removed to allow the flooded area around Kingfisher Lake to drain. The flap valve was relatively easy to remove, but the slider gate had rusted shut. Because it was underwater, it was hard to anticipate what would be required to remove it. Available equipment at the time included a backhoe with a front end loader combination and the standard front end loader.

The clay soils offered very little traction for the equipment. The front-end loader was used as a dead weight for the backhoe to prevent it from sliding forward while it pulled the slider gate out of the water. Chains were used around the gate to pull it out, but this put a lot of strain on the chains which could have resulted in them snapping. In hindsight, it would have been more efficient, and possibly safer, to have had a cutting torch and a larger excavator with a hydraulic chisel. As it was, it took approximately a day to remove the slider gate. Having the right tools on site may have resulted in a shorter duration of increased water turbidity and vibratory impacts to fish near the worksite.

Figure 23. *35 foot water tank for gravity-fed drinking water system.*

Figure 24. *Decommissioning failed septic tank.*

Figure 25

Figure 26

Figure 27

Figure 25. *Helicopter flight during restoration, August 2009. Photo credit, Duncan Berry.*

Figure 26. *Aerial view during restoration, August 2009. Photo credit Corrina Chase.*

Figure 27. *Aerial photo after restoration. October 10, 2014. Photo credit Grayson Lewis.*

Pixieland

BEFORE
Pixieland site in 1944. Highway 101 is not built yet. Highway 18 is diagonally across the lower right corner. The Salmon River is in the top of the photos.

DURING
Pixieland in 1984 before the buildings were torn down.

AFTER
Pixieland in June 2012 after the dikes were removed, the ditches filled in, the tide gate removed and the new stream channels were constructed in 2011.

Figure 28. *Oblique aerial photo, view to the west-northwest of Pixieland in 1975.*

History & Overview

In 1969 an amusement park called Pixieland was developed on 57 acres near the junction of Highways 101 and 18 by Lincoln City. By 1974, five short years later, Pixieland was bankrupt. To develop the site, the entire area was surrounded by a dike *(Figure 28)*. The dike also served as the railroad bed for a small train known as Little Toot *(Figure 29)*. Fraser Creek was routed into a ditch between the highways and the dike. Prior to the construction of Pixieland, Fraser Creek had been routed into a ditch along Highway 101. The developers of Pixieland extended the ditch upstream to the stream crossing under Highway 18. A tide gate was installed at the mouth of the Fraser Creek ditch and it was surrounded by a massive concrete structure and foundation. Fill material was added to the marsh to create a building surface. Shallow interior ponds and ditches were dug as part of the landscaping and to provide water rides.

Pixieland contained several buildings, roads, parking lots, a sewage treatment plant and a roller coaster ride called The Log Flume *(Figure 29)*. An RV park was built to the east of Pixieland. The RV park stayed in business until 1981.

In 1981, the Forest Service purchased the Pixieland and RV park properties as directed by the Cascade Head Scenic-Research Area Act. The buildings were torn down, leaving behind the concrete foundations, paved roads, parking lots, ditches, dikes and tide gate. The only remaining building was a small shed which housed the electric motor and mechanisms for the tide gate. Blackberries, scotch broom and reed canary grass had claimed the site.

On-the-ground restoration work began in 2007. The earthwork was completed in 2011. A more detailed summary of the restoration work accomplished can be found in the Appendix, page 50.

Planning

Unlike Tamara Quays, information on how Pixieland was built and the location of the infrastructure was very limited. Historic aerial photos showing the location of buildings was the best information available. Older historic photos were also consulted to determine where stream channels were originally located.

It was necessary for our team to drill the RV parking lot roads in several places to determine the thickness and therefore the amount of asphalt and subgrade that needed to be removed.

Similar to Tamara Quays, LIDAR mapping proved useful in determining the existing elevations and providing a base map for the AutoCAD grading plan drawings. LIDAR doesn't penetrate water, however, so depths of the ditches and ponds had to be measured in the field to determine how much material was needed to fill in the ponds and ditches.

Implementation required detailed plans for the grading and the stream channel construction. The new marsh surface needed to match the reference marsh elevation of 8.0 feet, and a detailed grading plan was produced in AutoCAD by the project engineer.

Figure 29. *Collection of photos from 1969 - 1974, during the operation of the Pixieland Amusement Park. Photo credits www.pdxhistory.com*

Figure 30. *The spruce trees on the dike along Highway 18 have been removed in preparation for leveling the dike.*

Figure 31. *Dike removal and ditch filling in progress along U.S. Highway 101. The highway is behind the trees on the right.*

Figure 32. *Dike removal. The fisheries biologist is looking for aquatic organisms in need of a last-minute rescue.*

Figure 33. *Finished dike removal along Highway 18. The highway is behind the trees on the left.*

Summary: Work Accomplished at Pixieland 2007– 2011

The main focus of the work done in 2007 was to clear away invasive plants and remove infrastructure. This included removing all the building and ride foundations *(Figure 42)*, plus removing 4,000 cubic yards of asphalt roads and parking lots *(Figure 43)*.

The work to restore Pixieland to a tidal marsh was so extensive it took over two summer work seasons *(Figure 38)*. A large part of the earthwork was done in 2010 when the interior of the site was the primary focus. Fill was removed from the marsh surface and pushed back into the interior ponds and ditches which had been excavated to accommodate amusement park rides. In total, over 27,000 cubic yards of fill was rearranged *(Figures 46 and 47)*.

The second phase of the earth work was done in 2011. Its focus was on restoring the hydrology of the area. The dikes and ditches along Highways 18 and 101 *(Figures 30-33 and 44)* were removed and new stream channels were dug for Fraser Creek through the wetland portion of the site *(Figures 34-37)*. The 2,000 linear feet of dike, which surrounded the amusement park and kept the tide out, were removed and 2,300 linear feet of ditches were filled to restore tidal marsh land. Fraser Creek had been heavily impacted by the amusement park development and the building of U.S. Highway 101. While constraints dictated where and how Fraser Creek was built, much thought and numerous iterations were considered before the job was completed (see page 50 in the Appendix). We constructed a 2,400 linear foot tidal channel and removed the last tide gate *(Figures 39-41)*.

Figure 34. *A small meandering stream channel was dug to provide natural drainage to the marsh surface.*

Figure 35. *The small channel is finished.*

Figure 36. *Digging the upstream portion of the new Fraser Creek channel just downstream of Highway 18.*

Figure 37. *Finished Fraser Creek channel at a moderate high tide in September.*

Figure 39

Figure 40

Figure 41

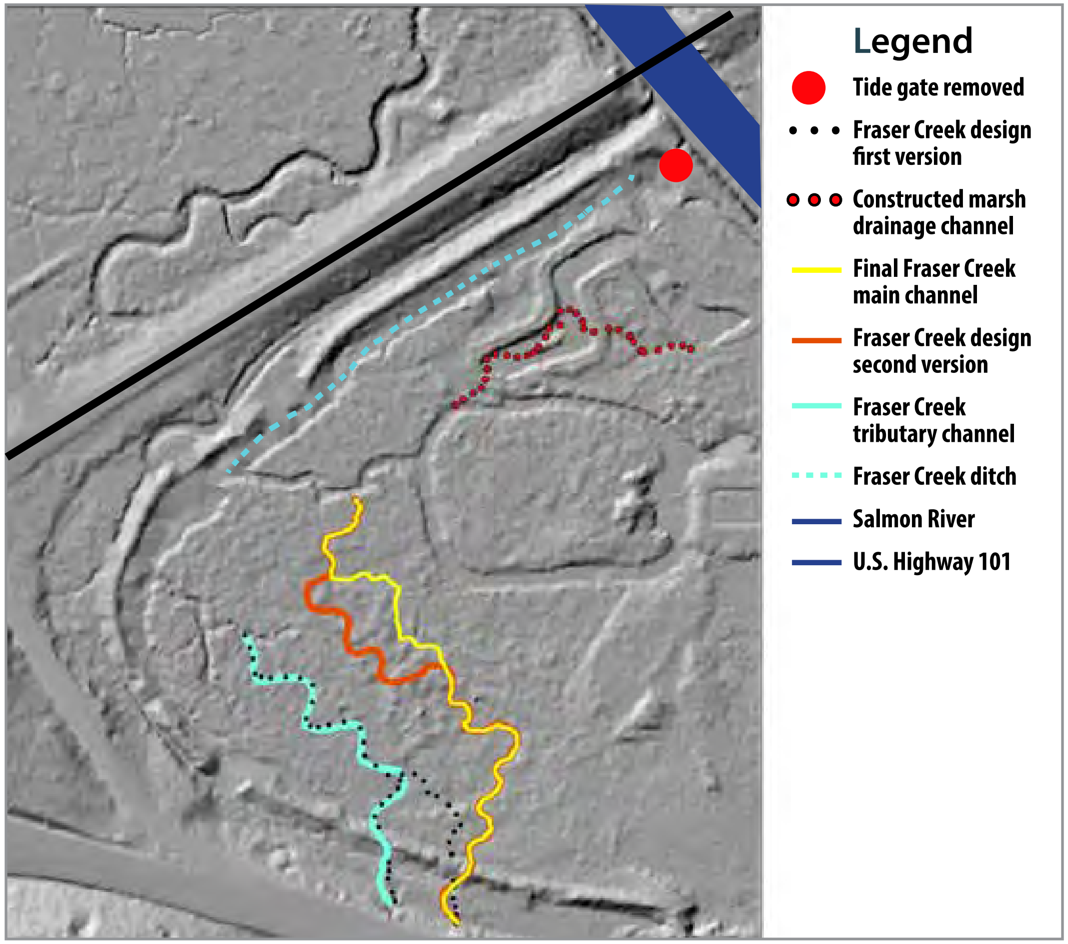


Figure 38

Figure 42

Figure 43

Figure 44

Figure 38. *Bare earth LiDAR image showing the new locations of the Fraser Creek channel and tributaries.*

Figure 39. *Last remaining Pixieland structure over tide gate.*

Figure 40. *Structure and tide gate removal.*

Figure 41. *The morning after the tide gate was removed, August 25, 2011.*

Figure 46. *Filling interior ponds.*

Figure 47. *Filling interior ponds.*

Figure 42. *Removing concrete foundations from an old sewage treatment plant site near the tide gate.*

Figure 43. *Pile of asphalt waiting to be recycled with a dump truck on top of it.*

Figure 44. *Removing trees from dike around Pixieland to facilitate its removal.*

Figure 45. *Fraser Creek tributary completed.*

Figure 45

Figure 48. *Installing the sediment curtain near the outlet of the tide gate in the Salmon River.*

Figure 50. *August 22, 2011 site prep for tide gate removal.*

Figure 51. *Removing the concrete around the tide gate, August 24, 2011. Jared Richey and Paul Lindsey pictured.*

Figure 52. *The morning after the tide gate was removed, August 25, 2011.*

Figure 49. *Last pass through waterway with seine net before remaining concrete is removed from tide gate area. Siuslaw National Forest Fisheries Biologists Jason Wilcox and David Skelton pictured.*

Lessons Learned at Pixieland

Tide Gate Removal During the summer of 2010, the water control mechanisms were removed from the tide gate culvert at Pixieland. In 2011, when we began to fill in the remaining ditches, there was concern that having the open culvert next to the river would create two problems. First, it would allow fish access to the work site from the river. Second, during high tides, water would backflow into channels and possibly raise the groundwater in the ditch we were trying to fill. Initially, attempts were made to block the outlet with the settlement curtain. This solution did not work because the tidal flow was stronger than anticipated and it pushed the sediment curtain into the culvert. We then purchased a steel plate large enough to cover the culvert outlet. This kept out most of the water.

Once the concrete box enclosing the metal culvert and supporting the small building housing the electrical mechanisms above the tide gate were removed, the metal culvert was then removed. This left the concrete sides and bottom of the box as the last pieces of infrastructure to be removed. On the days when the last of the concrete in the stream channel was removed, the sediment curtain was installed in the river at the outlet of the culvert. It required two people in dry suits to anchor the sediment curtain to the posts on either side and to anchor the bottom. The purpose of the sediment curtain was to control any turbidity plumes so the turbidity settled to the bottom of the river, rather than flowing into the water column. The sediment curtain worked very well for this. The work site was visible from the U.S. Highway 101 bridge over the Salmon River and no turbidity was noted in the river.

Figure 53. *Before: 1969, Main Street, Pixieland when the amusement park was in operation.*

Figure 54. *After: 2011, Main Street, Pixieland after restoration. This photo was taken in the same orientation as the 1969 photo (left).*

Figure 55. *Restored Pixieland marsh with a ten-foot tide and a three-day rainfall event, January 19, 2012. View is from the shoulder of U.S. Highway 101 looking south-east. This photo shows the extensive flooding of the restored marsh.*

Crowley Creek

BEFORE
1939 aerial photo of Crowley Creek and surrounding area before any ditches and dikes were built.

DURING
1952 aerial photo. Between 1944 and 1952 Crowley Creek and the marsh east of Crowley Creek had been diked.

AFTER
2012 aerial photo of Crowley Creek area immediately after the dike removal.

> "…dikes and ditches were built to convert the marsh land for agricultural use. By 1952 dikes had been built on both sides of Crowley Creek…"

History & Overview

The headwaters of Crowley Creek are on the southern slope of Cascade Head. It flows into the Salmon River on the eastern edge of Knight County Park. The 1939 aerial photo ("Before" above) shows the area before dikes and ditches were built to convert the marsh land for agricultural use. By 1952 dikes had been built along both sides of Crowley Creek and along the Salmon River ("During" above).

Summary

The first phase of restoring the Crowley Creek marsh was done in 1996 when the dike along the Salmon River was removed. For the first time in more than 40 years the marsh was open to the tides and the river.

Planning for phase two of the Crowley Creek restoration began in 2006 with a graduate student charrette. Shortly afterward the U.S. Fish and Wildlife Service surveyor did a topographic site survey of the area. Implementation of the work was delayed until the Tamara Quays and Pixieland projects were completed.

In the summer of 2012 the dike along the eastern bank of Crowley Creek *(Figures 62-64)* was removed. Additionally, a larger culvert was installed under Three Rocks Road for a small tributary to the west of Crowley Creek. During the restoration project, beavers dammed Crowley Creek and effectively dewatered the project area, removing several large trees each night *(Figures 64 and 65)*.

Within one year of this work being completed, the marsh vegetation in the dike removal area was well on its way to recovery *(Figures 56–58)*. Once the restoration ground work was performed at Crowley Creek and the dike was removed from the tidal marsh, it was a strip of bare soil *(Figures 60 and 61)*. Within one year, tufted hair grass became the dominant plant in this disturbed area. The planting efforts of the restoration team likely played a major role in this success, but seed brought in by the tide also likely contributed.

Other plants captured in the disturbed area have been established solely from local seed sources, also brought in by the tide. Bare ground and standing water make up the highest cover in the removed dike area. This is expected after only one year of plant colonization. Many of the non-native plants in the removed dike area either maintain a low, nonthreatening cover in the long term (i.e. spear saltbush) or are common pioneer species (e.g. toadrush).

Figure 56. *Braided channels of Crowley Creek following restoration. October 10, 2014. Photo credit Grayson Lewis.*

Figure 57. *The mouth of Crowley Creek following restoration. September 2012.*

The reference marsh transect captured a general tidal marsh plant community for the area which is mostly dominated by native plants. It is expected that the disturbed area, where the dike was removed, will develop in the same direction. While the cover of the non-native creeping bentgrass was high in the removed dike area, it also maintains a high cover in the reference marsh area. Reference marsh data from other projects in the area suggest it has become a component of these tidal marshes and the native plants appear to coexist.

Figure 58. *Aerial photo looking upstream at Crowley Creek following restoration. October 10, 2014. Photo credit Grayson Lewis*

Figure 59. *August 2012 prior to the removal of the dike. The view shows the end of the dike near the mouth of Crowley Creek looking upstream.*

Figure 60. *August 2012 immediately after the dike was removed. Crowley Creek is on the left side of the photo, view to the north. This photo was taken in September when streams and rivers are at their lowest flows and the ground is dry.*

Figure 61. *November 2012 looking across Crowley Creek. Restoration completed August 2012.*

Figure 62. *Looking across Crowley Creek at the spruce trees growing on the dike.*

Figure 63. *Excavator removing spruce trees and dike, freeing Crowley Creek from the ditch.*

Figure 64. *High tide at Crowley Creek after restoration. January 2013.*

Figure 64. *Industrious beaver helped with the restoration effort by felling trees during the night.*

Figure 65. *Beaver dam on Crowley Creek, upstream of Crowley Creek restoration project. Resident elk herd in the background. Photo credit Duncan Berry.*

Boat Basin

BEFORE
1961 aerial photo of the Mink Creek area. Mink Creek is the wide, meandering channel in the right of the photo. Note the mouth of the creek appears to have a road crossing over it.

IN DEVELOPMENT
2005 aerial Google Image of the Boat Basin area.

CURRENT
Aerial photo of the Boat Basin October 10, 2014, after restoration. Photo credit Grayson Lewis.

"…intended to be a boat mooring basin, the Boat Basin was dug on the North side of the Salmon River in the late 1960's."

History & Overview

An L-shaped ditch, intended to be a boat mooring basin, was dug on the north side of the Salmon River in the late 1960s *(Figure 72)*. It was to be an amenity associated with a large proposed housing development on the nearby hillside. The ditch was dug prior to the passage of the Cascade Head Scenic-Research Area Act, but further development of both the marina and the housing project was halted.

The 60-foot wide ditch *(Figure 67)* had altered the hydrology of the nearby area. Mink Creek was diverted into the ditch. A tributary parallel to the Salmon River was cut by the north-south leg of the ditch and the western portion of the tributary reversed flow. The eastern portion of the tributary was buried under the spoils from the ditch. A freshwater wetland with cattails developed in the area. It was impounded by the berm to the west and north, and to the south by the elevated levee along the Salmon River.

Planning

Planning the Boat Basin restoration project relied on historic aerial photos of the area, bare-earth LiDAR images *(Figure 66)* and a topographic site survey. Using this material, several alternatives were considered in tackling this restoration project. The first option considered was to remove the berm and use the material to narrow the width of the boat basin ditch, leaving the channel in the middle of the ditch. This alternative was not considered viable because of the difficulty of compacting the fill. It was also assumed winter storms and high tides would mobilize the fill material. The second option considered was to remove the berm, fill in the boat basin ditch and reconstruct the Mink Creek channel in its original 1944 location.

This alternative was not developed for the following reasons. First, the drainage pattern visible on the 1944 photo shows a subtle drainage divide between Mink Creek and its small tributaries to the stream network just west of it *(Figure 68).* A site survey was conducted and it also picked up a slight rise between the old location of Mink Creek, which is now filled in, and the ground now occupied by the dammed pond to the west. The reason for this slight rise isn't obvious, but it kept Mink Creek in its own small watershed. Another reason this option wasn't considered was that the area around Mink Creek has been significantly altered. The boat basin ditch completely disrupted the local hydrology. It was carved through the slight drainage divide separating Mink Creek from the drainages to the west. It also captured other tributaries and changed their direction of flow *(Figure 69).* By the 1960s the mouth of Mink Creek had been blocked or altered *(Figure 68).*

Finally, when an equipment operator visited the site, he thought the area around the former mouth of Mink Creek was too wet to support heavy equipment. It would have been necessary to build a temporary road to reach the channel construction site and then deconstruct the road.

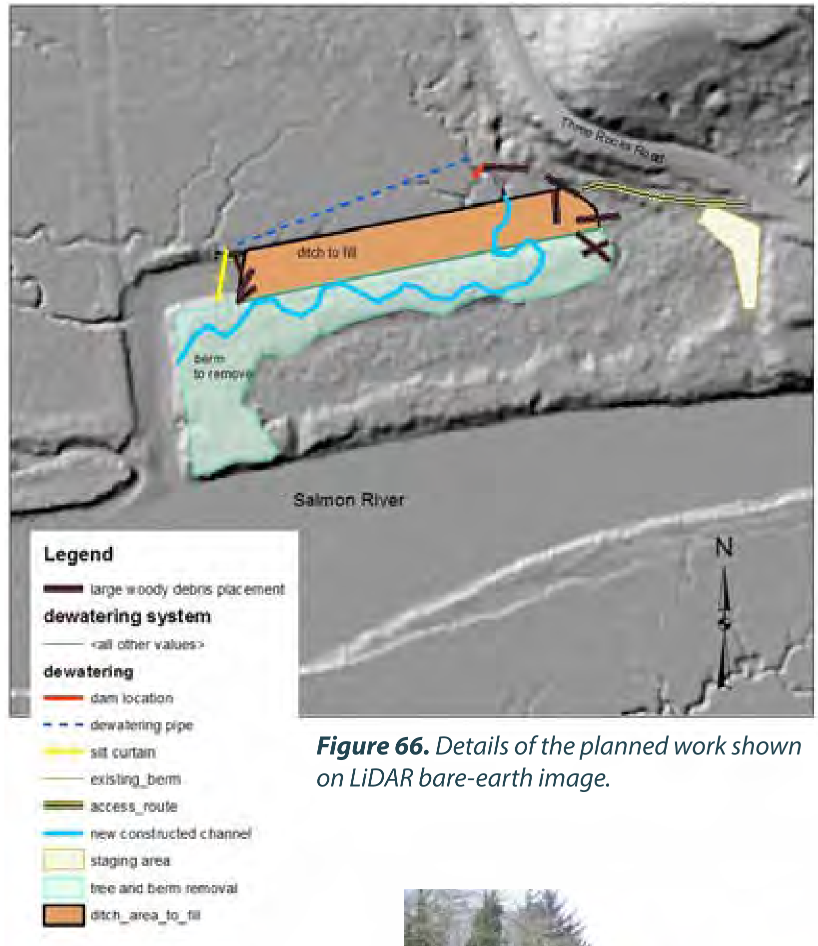


Figure 66. *Details of the planned work shown on LiDAR bare-earth image.*

Figure 67. *Boat Basin ditch before restoration, May 2014.*

Figure 68. *1961 aerial photo of the Mink Creek area. Mink Creek is the wide, meandering channel in the middle of the photo. Note the mouth of the creek appears to have a road crossing over it.*

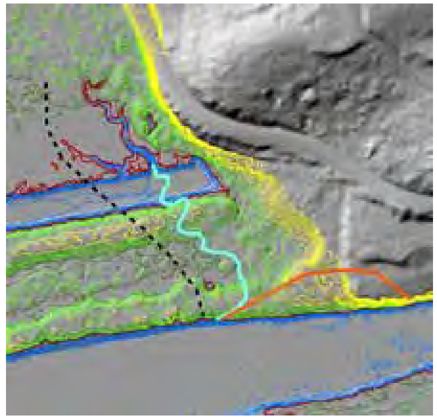


Figure 69. *1944 features shown on the 2007 LiDAR map. The black dotted line is the drainage divide shown in the 1944 photo. The light blue line is the 1944 location of Mink Creek. The orange curved line is the sandbar and side channel location along the river in 1944. It has been filled in by the attempt to develop the area.*

Figure 70

Figure 70. *Proposed work shown with a Google earth image as the background.*

Figure 71

Figure 71. *Aerial photo after restoration. October 10, 2014. Photo credit Grayson Lewis.*

Figure 72. *May 2014 view from the dike before work began.*

The option finally chosen was to remove the berm and the trees growing on it. Then the berm material was used to fill in the ditch and a new channel for Mink Creek was constructed over the location of the parallel tributary *(Figure 66 and 70)*. The large amount of wood removed from the berm was used to reinforce the end of the fill material in the ditch and was then scattered on site.

There were numerous benefits to constructing Mink Creek to its 1944 parallel tributary location and not its original 1944 location *(Figures 68–69)*.

- Constructing the channel in the location of the berm reduced ground disturbance and minimize the amount of vegetation that had to be removed.
- Heavy equipment didn't have to be driven on a vegetated marsh surface, which would potentially create ruts that could develop into potholes or linear stream channels. Ruts had been created when an excavator was used on the Pixieland marsh to mow reed canary grass.
- The waste fill created from excavating the nearby channel was added to the Boat Basin ditch with a minimum of disturbance.
- Placing Mink Creek in its original 1944 location would have created a risk of scour due to the current elevation of the river levee. Mink Creek would need to cross the levee in order to connect with the river.

Figure 73

Figure 74

Figure 75

Figure 76

Work Accomplished at Boat Basin in 2014

The restoration of Boat Basin occurred in 2014. It began by building a temporary access road for equipment. Then the trees growing on the berm were removed. The alder was used for firewood, while the spruce trees were used as large woody material on site. Fisheries biologists installed block nets at low tide to keep fish from entering the work area and swept the area to ensure that nothing had been trapped within the ditch.

Next, we constructed a dam across the Boat Basin ditch and reinforced it with large woody material from the berm. The berm fill material was used to fill the ditch *(Figure 73)*. Finally, we dug a new channel six feet wide for Mink Creek *(Figure 71, 74-76 and 79)*. Figures 77 and 78 show the first incoming tide at 9:00pm on August 6, 2014.

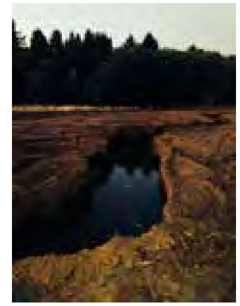


Figure 77

Figure 78

Figure 73. *Large berm removed and ditch filled. Site is ready for Mink Creek construction. August 5, 2014.*

Figure 74. *Mink Creek channel construction. August 6, 2014.*

Figure 75. *Eight foot tide in Mink Creek. September 10, 2014.*

Figure 76. *Aerial photo of Mink Creek and Salmon River Estuary. October 10, 2014. Photo credit Grayson Lewis.*

Figure 77 and 78. *First returning eight foot tide into Mink Creek. 9:00pm on August 6, 2014.*

Lessons Learned at Boat Basin

Filling the Ditch: Filling a ditch as wide as the Boat Basin (60 feet or greater) proved far more challenging than filling the smaller ditches at Tamara Quays and Pixieland. It might have been easier to section off segments of the ditch with coffer dams at intervals, allow the black muck between the filled areas to dry out, and then fill the remaining ditch segments. This option might have resulted in better compaction.

Digging the New Channel: In order to achieve a zero percent gradient to Mink Creek, and connect the mouth's elevation to the existing channel elevation just north of the ditch, the banks had to be approximately eight feet high. To avoid excessively high banks which would cave in and potentially be dangerous, the banks were dug to a depth of no more than five feet high. As a result, flow from Mink Creek is ponding near the connection. The old marsh surface was marked by a buried grass layer covered with approximately eight inches of sand. It was found at a depth of five feet. This horizon probably denotes the surface of the marsh subsided during the subduction zone earthquake in 1700.

Figure 79. *Aerial photo of Mink Creek and tributary channel during a receding 9.5 foot tide. October 10, 2014. Photo credit Grayson Lewis.*

U.S. Highway 101

BEFORE

1944 photo prior to the construction of Highway 101.

DURING

U.S. Highway 101 under construction in 1961. The bridge over the Salmon River is not yet in place. Salmon Creek to the northeast of the river has been rerouted into a ditch. Fraser Creek has also been rerouted into a ditch on the other side of the river.

CURRENT

2010 aerial photo showing current condition of U.S. Highway 101 across the Salmon River estuary. Phase I of the Pixieland restoration has been completed.

"…Salmon Creek and Fraser Creek were truncated by the highway and routed into ditches on the east side of US Highway101."

History & Overview

In 1961, an earthen dam was built across the Salmon River estuary to allow for the construction of U.S. Highway 101 *(Figure 83)*. This dam divided the estuary into a tidal wetland on the west side and freshwater wetland on the east side. The only opening in the dam is a bridge over the Salmon River.

Salmon Creek and Fraser Creek were truncated by the highway and routed into ditches on the east side of U.S. Highway 101. Fraser Creek (a smaller system to the south of the Salmon River) and Salmon Creek (north of the Salmon River) do not currently function as tidal or freshwater systems. Currently these altered channels do not provide the kind of salinity gradient that rearing salmonids need to make a successful transition from freshwater to the ocean. The remaining remnant channels on the west side of U.S. Highway 101 are dead end tidal channels which rise and fall with the incoming and outgoing tides. The channels of both Fraser Creek and Salmon Creek on the east side have been heavily altered by ditching, diking and tide gates *(Figure 80)*. Fraser Creek was rerouted and split into two flow paths when Pixieland was built and tidal flow was controlled with a tide gate. Salmon Creek was placed in a ditch that has not been maintained. The ditch has filled with sediment and the creek breaches the ditch in several places during high water events.

Figure 80. *2011 aerial photo of U.S. Highway 101. Since 1961 Salmon Creek has been rerouted into the ditch (parallel to U.S. Highway 101). The historic Salmon Creek (to the right of U.S. Highway 101 and below Salmon River) is truncated by the highway. Photo credit Anthony Veltri.*

Summary

We are currently pursuing ways to reconnect Fraser Creek and Salmon Creek with openings under U.S. Highway 101 to restore tidal inundation to the east side of U.S. Highway 101. Siuslaw National Forest secured approximately $200,000 for a preliminary survey, geotechnical work and a preliminary assessment of National Environmental Policy Act (NEPA) and National Oceanic and Atmospheric Administration (NOAA) requirements. The Siuslaw National Forest also secured funding for a hydraulic study of the tidal prism under current and historic conditions, as well as with multiple bridge openings, to reconnect both tidal flow and Fraser and Salmon Creeks.

Fraser Creek and U.S. Highway 101

Oregon Department of Transportation (ODOT) will build a crossing for Fraser Creek on U.S. Highway 101 during the summer of 2015. After the crossing is complete the Forest Service will fill the ditch emptying into the Salmon River.

Fraser Creek was cut in two by U.S. Highway 101 and a ditch was dug parallel to the highway on the southeast side to connect the upstream portion of Fraser Creek to the Salmon River *(Figure 81)*. The downstream section of Fraser Creek is just northwest of U.S. Highway 101 and was left as a remnant channel.

Figure 81. *Fraser Creek was cut in two by U.S. Highway 101. A ditch was dug parallel to the highway on the southeast side to connect the upstream portion of Fraser Creek to the Salmon River. The downstream section of Fraser Creek is just northwest of U.S. Highway 101 and was left as a remnant channel.*

Salmon Creek and U.S. Highway 101

Background: Salmon Creek drains off the east side of Cascade Head. It was relocated into a ditch along U.S. Highway 101 when the highway was built in 1961 *(Figure 82)*. A berm that was built along the ditch has breached in several places and fish are being washed out of the ditch into the meadow (*Figure 84*). The berm is on Oregon Department of Transportation's right-of-way.

Proposed Work: The Siuslaw National Forest is proposing to build a new meandering channel for Salmon Creek that bypasses the ditch and berm breaks. *Figure 85* shows a design concept and approximate location for this effort. U.S. Highway 101 was built on top of the historic channel, therefore, Salmon Creek cannot be restored to its historic location. In this proposal, however, the gradient and sinuosity of the historic channel would be restored, creating a sustainable stream system. Currently, Salmon Creek is forced into a straight line, any gravels moving down Salmon Creek deposit and fill the Salmon Creek ditch. This causes it to fail during high flow events. Additional work may include reconnecting Salmon Creek with the remnant channel northwest of U.S. Highway 101 by building a bridge, or other crossing at U.S. Highway 101. Making these changes will restore the valuable salinity gradient that anadromous fish in this system are seeking and rely on to aid in their transition from fresh to salt water. For this to occur it is important the tidal channels are connected to their fresh water sources.

This proposed work would require the permission of the private land owner.

Figure 82. *1961 aerial photo of U.S. Highway 101 under construction. Salmon Creek has been relocated into newly constructed ditches.*

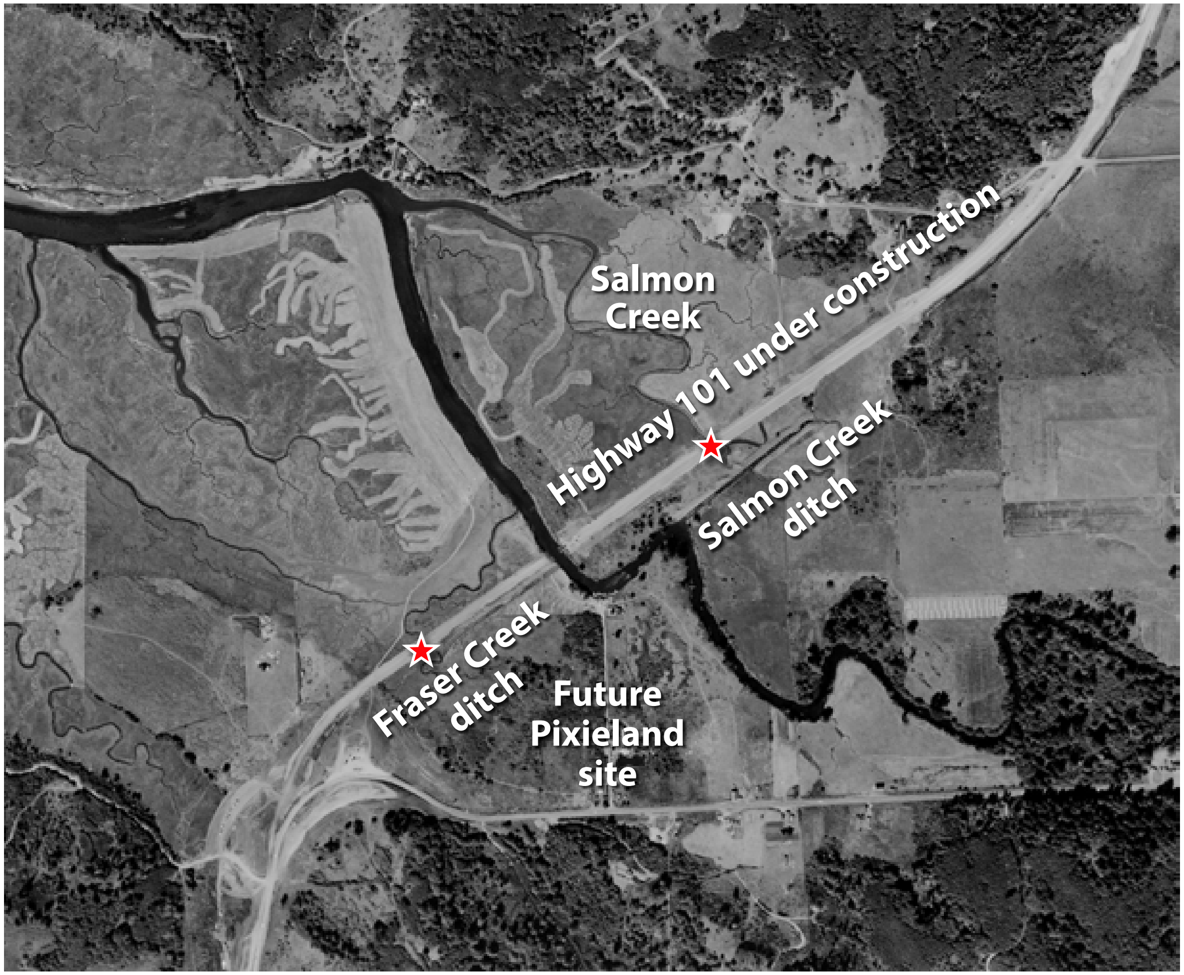


Figure 83.*1961 aerial photo of U.S. Highway101 under construction. Salmon Creek and Fraser Creek have been relocated into newly constructed ditches.*

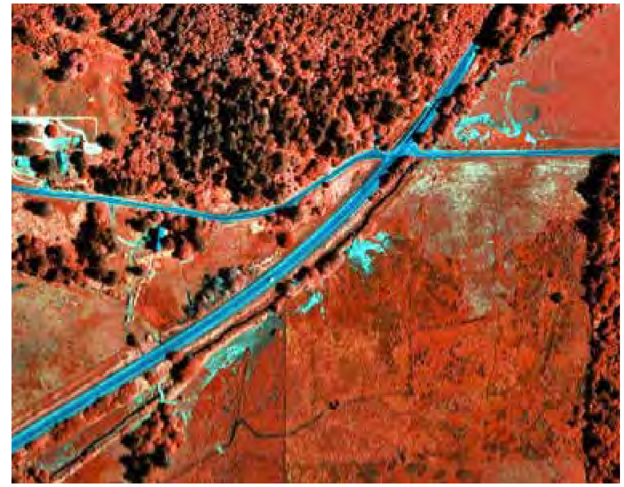


Figure 84. *Berm breaks – Color infrared photo (2000) shows breaks in the berm (aqua color) along the Salmon Creek ditch.*

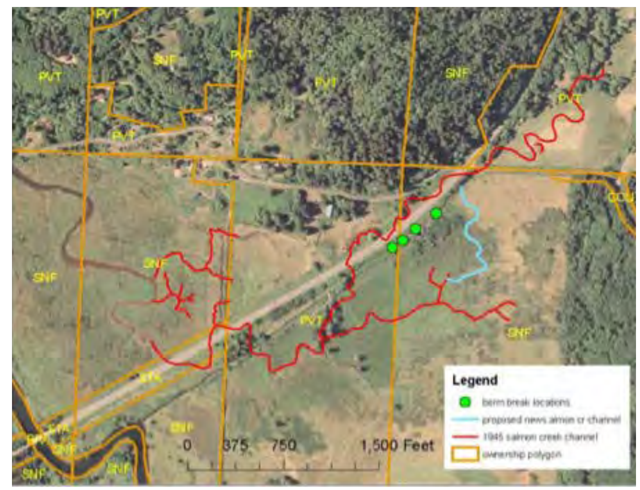


Figure 85. *This is the design concept for a new channel which will bypass the breaks in both the ditch and the berm along U.S. Highway 101. The red line is the historic location of Salmon Creek prior to the construction of U.S. Highway 101 in 1961. The blue line is an approximate location for a new meandering channel for Salmon Creek. It would bypass the berm breaks (green dots).*

Lessons Learned: Salmon River Estuary Restoration Overview

Planning

Large, complex projects require time and an interdisciplinary approach. Allow the team members adequate work time to incorporate data from a variety of sources, and discuss the pros and cons of different plans.

Acquiring the necessary permits from state and federal regulatory agencies can be a drawn-out process. For the Salmon River projects, numerous permits were needed before work could begin. These permits included the joint fill-removal permit issued by the Army Corps of Engineers and the Oregon Department of State Lands (ODSL). A lead time of at least six months is advisable. A Right-of-Entry Permit from ODSL was required to access tidally influenced lands. A permit from the Oregon Department of Transportation (ODOT) was required to work in their right-of-way along Highways 18 and U.S. Highway101. The ditches and dikes at Pixieland *(Figure 86)*, and a portion of the Tamara Quays property, are owned by ODOT. For restoration sites that were in a mapped floodplain, permits were needed from Lincoln County for altering a floodplain.

Finally, an in-water work variance was required from the Oregon Department of Fish and Wildlife (ODFW) with concurrence from the National Marin Fisheries Service (NMFS). For Oregon estuaries, the standard in-stream water work periods occur in the winter. During the summer, juvenile Chinook and coho salmon are moving downstream to rear in the estuaries. For this reason, the in-water work period is usually in the winter to avoid the high fish numbers present in the summer. However, that is also when the water is highest and it is not possible to work in the marsh with heavy equipment. Therefore, a variance from the usual winter work period was needed to work during the summer.

To facilitate the permitting process, the persons in charge of issuing the permits were contacted early in the planning process. Site visits with the regulatory agencies' personnel were very helpful. It allowed them to see the proposed work and gain a better understanding of the desired goals. It is important to give the regulators enough lead time to review the permits and issue them in a timely fashion.

A number of data sources were especially useful during the planning process. They include:

LiDAR: LiDAR was acquired in November 2007. It provides detailed topographic information of the entire estuary. In the long run, it saved the restoration team the time, effort and expense that would have been needed for total-station topographic site surveys.

As-built planning documents and correspondence: The Lincoln County Planning Department provided correspondence about the sites, as-built maps that showed the location of underground pipes and utilities, as well as the original plat map. The information from the county planning department helped the team anticipate what infrastructure might be encountered during the excavation and earthwork.

Historic aerial photography: Historic photos are valuable in showing the pre-development hydrography and condition, as well as the progression of the developments. They were used to determine the reference condition, and served as a guide for the restoration goals, as well as showing where old building foundations and infrastructure might be located.

Infrared photography: The Environmental Protection Agency (EPA) has flown infrared photography of most of the Oregon estuaries. This gave another perspective of the vegetation and wet areas.

Figure 86. *Pixieland Amusement Park Restoration Plan.*

Project Implementation

It is important to establish a chain of command. The chain of command was laid out in the following manner. The Salmon Drift Watershed Council, the Siuslaw Nation Forest Watershed Program Manager and Forest Hydrologist provided the project planning and oversight. For several of the more rigorous restoration projects a Forest Service engineer served as a liaison with the Salmon Drift Watershed Council and project superintendent. The engineer worked on developing the equipment rental contracts, determined specific contract specifications and generally made sure the work proceeded smoothly. One of the Forest Service equipment operators served as the job foreman. They planned the daily and weekly flow of work and supervised the other Forest Service equipment operator employees and private contractors.

This chain of command worked well. We cannot stress enough that it is important everyone understand their roles in the project. In work this complex, it is difficult to bring people into the middle of the project and get them up to speed quickly. Therefore, if it is possible, keep the same people on the project for its duration.

One person should be in charge of the day-to-day operations to avoid communication mix-ups. A communications plan is helpful. Make a list of cell phone numbers and who should be contacted about various issues that may arise. Make a list of back-up personnel and share it with all involved. Discuss when key personnel anticipate not being available in advance.

Before the project implementation begins, it is important to have a logical sequence of work planned and discussed with those involved. Several disciplines are usually involved in these complex projects. For instance, the fisheries biologists needed lead time to capture and remove fish and other aquatic species from the ditches as they were being dewatered. The installation and removal of coffer dams and dewatering systems had to be staggered. The sequence of work involved in removing the dikes and filling ditches had to be carefully planned.

The seasonal work window, determined by USFW's needs, was July 15 to September 15. Because there were only two months of time to do the work, the implementation had to be planned carefully. The work schedule for the equipment crew was five days a week, 12 hours per day. This schedule allowed for efficient use of the rented heavy equipment and allowed the work to be accomplished in the two month time frame.

The crew only has one chance, or one pass, to access a spot and do the work. It's not possible to make multiple passes with equipment, as the ground surface will start to break down.

The time of day when work in tidally influenced areas is done is determined by the timing of the tides. Again, work needs to be planned accordingly. Critical work influenced by the timing of the tides included the removal of the tide gates and digging new stream channels. In the case of removing the tide gate at Tamara Quays, there was a 30 minute window at low tide when the equipment could pull out the tide gate. At Pixieland, ditches drained to the river on either side of the dike. The 50-year-old trees growing on the dike had to be removed and there was no place to fall the trees except into the ditches. It was important to time the work with the outgoing tide so the possibility of fish being present would be minimized.

During the construction phase, the work went more efficiently if the day-to-day implementation was planned a week at a time. Because there were so many unknowns in the project, trying to plan out the entire season at the beginning of the work was impractical. In the case of Tamara Quays and Pixieland, the unknowns usually involved lack of information about buried infrastructure.

Fish Populations Response

Rowdy Creek and Fraser Creek provide valuable estuary margin habitat. The Oregon Department of Fish and Wildlife (ODFW) has noted a high use of these creeks by juvenile coho salmon at several sites along the north shore of the Salmon River estuary. In winter, some yearling coho will seek shelter in these small tributary backwaters from the high winter flows for up to three months before heading out to the estuary and on to the ocean in the spring. Later in the spring and summer, a new age class of sub-yearling coho uses the freshwater or brackish areas of the estuary to rear. This group of fish may go out into the ocean in the fall, go back upriver or stay in the estuary and surrounding habitats for a few months until the spring migration.

ODFW has conducted frequent sampling at Rowdy Creek, Tamara Quays and at Fraser Creek in Pixieland. Fish populations and use after the restoration cannot be quantified because the data was not collected before these projects were implemented. ODFW fisheries biologists, however, saw an immediate use of these habitats by salmon after the restoration was finished. Sampling done in Rowdy Creek in November 2009 counted 19 juvenile coho who were probably staying until spring. In December 2010, juvenile coho were observed actively trying to jump an old beaver dam on Rowdy Creek above the tidally influenced restoration area, and the replaced culvert, in order to access the freshwater marshes upstream.

ODFW sampled the Fraser Creek channel with a fyke trap net on May 31, 2012 near the mouth where the tide gate had been removed in 2011 *(Figure 86)*. They caught 22 juvenile Chinook and 16 juvenile coho (sub yearlings), as well as hundreds of three spine sticklebacks. It has been ODFW's experience that coho can stick around Fraser Creek throughout the winter and migrate out to the ocean in the spring.

Figure 87. *ODFW sampling the mouth of Fraser Creek for fish (Pixieland). The tide gate was removed from this spot in 2011.*

Social Impacts

The Salmon River estuary is a high-use, high-visibility area. The public has had a deep concern about the future of recreation and protection of this area and there is not always agreement about management decisions. For example, some people would like to expand recreation development, while others would prefer to see public access remain static. It is often difficult to balance diverse interests. The student charrette successfully incorporated input from the local community which resulted in restoration recommendations that people could agree on and support.

Developing partnerships with different federal and state agencies, as well as non-government organizations, allowed funding and success of this complex restoration effort. Some of these partners included, the Oregon Watershed Enhancement Board, Salmon Drift Creek Watershed Council, U. S. Fish and Wildlife Service, The Nature Conservancy, Oregon Department of State Lands and the Oregon Department of Transportation.

Funding and Grants

All of this work was primarily grant funded. The Siuslaw National Forest, with critical support from the Oregon Watershed Enhancement Board, submitted a grant to the U. S. Fish and Wildlife Service National Wetland Conservation Grant Program. The grant required state funding as a match and could not be submitted by one federal agency to another federal agency. Partnerships with the Oregon Watershed Enhancement Board and the Salmon Drift Creek Watershed Council were vital to the success of the Salmon River estuary restoration.

Agency/Organization	Funding	Year
Oregon Watershed Enhancement Board	$350,000	2007-2011
USFWS Coastal Wetland Grant Program	$457,000	2007-2014
Oregon Department State Lands	$300,000	2007-2017
Salmon Drift Creek Watershed Council	In-kind	2006-present
Oregon Department of Transportation	$97,000 + additional in-kind	2009 & 2011-2014
Siuslaw National Forest	$400,000	2006-present

Project	Number of Retained Local Contractors	Dollars Paid to Local Contractors	Dollars Paid to Local Vendors	Number of Involved Watershed Council Employees	Dollars Received by Watershed Council	Total Direct Restoration Dollars
Tamara Quays	15	$218K	$36K	4	$14K	$268K
Pixieland	19	$385K	$27K	5	$86K	$498K
Crowley Creek	12	$62K	$18K	1	$30K	$110K
Boat Basin	5	$103K	$13K	1	$22K	$138K
TOTAL	51	$768K	$94K	-	$152K	$1,014M

Figure 88. *Salmon River estuary sandspit at the mouth of the river taken from the top of Cascade Head. July 11, 2013. Photo credit Kami Ellingson.*

Aquatic Organism Rescue

An important part of the project was recovering and removing any aquatic organisms present in the work areas' waterways. Before draining the ditches, nets were installed to isolate sections of the ditches. As ditches were slowly drained, the fish and any other aquatic organisms were herded toward the downstream nets. ODFW personnel and volunteers would then capture the fish in hand nets, put them in buckets of clean water and transport them to a safe release site *(Figure 89)*.

As with other aspects of this complex restoration project, lessons were learned that will make it easier the next time. First, in marsh environments the creeks often have soft, slippery, muddy bottoms. Do not put crew members in situations where they have to move around a lot and risk losing their footing. Instead, it is better to have strength in numbers. Have several crew members stationed in the creek or ditch and along the bank so they can pass buckets containing recovered fish from person-to-person.

Next, make sure there is a large amount of cold, clean, well aerated water available for the buckets. Don't forget to change the water frequently. Transport the fish as quickly as possible to the release sites and away from the work area.

Rather than installing one downstream net and trying to herd the fish toward it, consider dividing the stream channel into several smaller segments with several nets. The smaller areas will make it easier to capture the fish. It is important to select pumps with a large enough capacity to dewater the ditches. Coordinate with fisheries personnel about fish screens on the intakes and pump operation so aquatic organisms are not stranded or killed.

One person should be designated as a coordinator for fish relocation. During the period of time when this recovery and relocation is occurring, this should be the coordinator's sole task, especially if it's a large area.

Also related to staffing, recruit and schedule more crew members than you think you will need. Have backup crew members in case someone is absent. When volunteers are present take advantage of this opportunity for informal education. Topics to cover and discuss can include aquatic ecology and species identification.

Photos of fish removal and recovery can also be good publicity for the project. The public affairs person was on-site in 2010 to take photos of the fish recovery. These photos were used in local newspaper articles and helped inform the public about the restoration work.

Figure 89. *Fish seining near the outlet of the tide gate in the Salmon River, during Pixieland restoration. Jason Wilcox and David Skelton pictured.*

Dealing with the Unforeseen

Issues that cannot be anticipated, regardless of the attention paid to planning, inevitably come up. The ability to solve problems as they arise is critical. Here is one example of an unforeseen issue that came up during implementation and our creative solution.

Reed canary grass had become the dominant vegetation on the Rowdy Creek marsh surface at Tamara Quays *(Figure 94)*. When excavation began to remove the fill, about half the depth was reed canary grass and its roots. We realized it wouldn't make good fill material for the ditches. Also, disposing of it off-site would be prohibitively expensive. Since it is considered a noxious weed, it is treated as hazardous waste if it is removed from the site. A disposal site was needed immediately, so the sod was piled up in the old septic drain field in the upland area and covered with landscape cloth.

Select the Right Equipment

Selecting equipment that will have minimal impact is important. Low ground pressure machines are needed when working in marsh environments to minimize soil displacement, rutting and compaction. Wheeled machines do not work well in a marsh environment. Another way to prevent rutting by equipment is to use debris mats, such as branches and slash.

A tracked dump truck was essential for removing the dike at Tamara Quays and for digging the new stream channels at Pixieland. Advantages of this truck were that it could turn 180 degrees on its base. Therefore, it could operate where space was limited, such as the top of a dike. The dikes were in disrepair and riddled with nutria (rodent) burrows. A regular wheeled dump truck would have gotten a wheel stuck in a hole. The tracked dump truck could also travel across the marsh surface without causing compaction.

As an experiment in efficiency, a scraper was used at Pixieland for a day to see if it was more efficient at moving dirt. Both the scraper and an excavator-dump truck combination were timed and production was evaluated. The scraper was not as efficient as the excavator-dump truck combination. The preferred equipment for this type of work is a combination of one or more excavators, a tracked dump truck and a regular dump truck.

Rent quality equipment that includes timely maintenance support with quick repair and replacement *(Figure 91)*. This will prevent slowing down the project's progress. Balancing the trade-off of sourcing specialized equipment locally, with getting the right equipment from further away (with a more expensive mobilization costs), can be critical to project efficiency.

To decommission old roads, the road surface was roughened with the bucket of an excavator or a brush rake. The ripper teeth on the bulldozer were not used. The bucket ripping or brush rake allowed for more infiltration and less chance of gully erosion.

A thousand gallon fuel tank was kept on site to refuel the heavy equipment. This situation was more cost effective and efficient than bringing a fuel truck to the site every couple of days.

At both Tamara Quays and Pixieland, creating a new marsh surface at the right elevation was critical to achieving the restoration goals. A laser level with the receiver (eye) attached to the blade of the bulldozer *(Figure 90)* gave instant on-the-go elevation readings and the operator could adjust the blade accordingly. As a result, most of the new surface elevations matched the reference elevation.

Figure 90. *RA laser level eye was mounted on the blade of the bulldozer. This allowed for precise grading in an efficient manner.*

Figure 91. *The last of the dike removal at Tamara Quays. September 2009*

Figure 90

Figure 91

Dealing with the Saturated Soils in the Ditches and Ponds

The soil in the bottom of the ditches and ponds was a water-saturated, organically-rich, fine-grained, anoxic material. We nicknamed it "marsh muck" or "black goo" (*Figure 93*). As fill material from the dikes was pushed into the ditches, the saturated black goo would be pushed ahead of the fill down the ditch. It resembled a slow moving wave of black tapioca pudding. Because we did not want to push the black goo out of the project area and into the estuary channels, it was extremely difficult to fill the ditches.

At Tamara Quays the solution included the following steps.

1. Build a coffer dam at the end of the ditch to contain the black goo.
2. Pump out the water in the ditch.
3. Fill the ditch with the dry dike material above the desired final grade.
4. Wait a week for the black goo to dry out and settle.
5. Shape and compact the ditch fill with a small, low ground pressure bulldozer.

In some instances, to speed up the work, the black goo was dug out of the ditches or ponds and placed on upper ground surfaces where it was allowed to dry out. The ponds or ditches were then filled with dry fill material and graded. The piles of black goo that were dug out of the ditches were then graded and mixed into the new marsh surface. This method wasn't as satisfactory as leaving the black goo in place. The goo still had to be allowed to dry out and graded into the marsh surface at Pixieland. If time had been available, it would have been better to allow the black goo to dry out in place.

Figure 92. *An egret standing along the bank of Rowdy Creek during the restoration of Tamara Quays.*

Figure 93. *The black goo, or marsh muck, collected behind the coffer dam in the ditch. As the fill was added it pushed the muck toward the end of the ditch. The excavator operator used the bucket to scoop out the muck and place it on the marsh floor behind the excavator.*

Figure 94. *The marsh surface at Tamara Quays with native rush and grass becoming established. Rowdy Creek on the right of the photo. The upland area is planted with native trees, protected by white plastic tubing, can be seen upper left (2011).*

Vegetation Restoration, Management and Noxious Weed Control

Vegetation restoration had three objectives: restoration of the native plant community, erosion control and the control of noxious weeds. Restoring the native vegetation and controlling the weeds is discussed below.

Native vegetation restoration began with a planting plan. In an estuary, plant selection and successful establishment is dependent on the site's elevation above mean high tide and the salinity. Initially, site-specific plans were created based on assumptions about the slopes and elevations that would be on the ground after the earthwork was completed. These plans were based on the first conceptual plans for the earthwork. As the earthwork progressed over the years some of the grading plans changed and the elevations were different from the original assumptions. In hindsight, it would have been more useful to create species lists and plans for generic vegetation zones based on elevation and slope and then match these vegetation zones to the ground after the earthwork was completed *(Figure 94)*. The as built, a detailed topographic survey done after the earthwork was completed, was very useful in planning the vegetation work, especially at Pixieland.

Native species chosen for the two sites include western hemlock (*Tsuga heterophylla*), red alder, Sitka spruce, western red cedar (*Thuja plicata*), vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), common snowberry (*Symphoricarpos albus*), pacific ninebark, and red elderberry.

If there is enough lead time it is useful to grow the plants and seeds from local stock. For this project the commercially available seed came from the Puget Sound or the Willamette Valley. The Salmon Drift Watershed Council is working on developing local seed sources.

The restoration efforts provided an opportunity for experimentation. A Master of Science student (Summers, 2009) experimented with the best ways to control invasive weeds, especially reed canary grass, and establishing native trees and shrubs in the restoration project areas.

At Tamara Quays transects of willow cuttings *(Figure 95)*, Douglas spiraea plugs, small-headed bulrush plugs (*Scirpus microcarpus*) and soft rush (*Juncus effusus*) were planted perpendicular to the contour from Rowdy Creek into the upper elevations next to the marsh. Below are the results after one year.

The willow survival seemed to be better away from the edge of the creek. Many of the surviving cuttings were in poor condition; some only had new leaves near the base. This may be related to the timing and condition of the original plantings or to the environment where this was observed. The condition after the next growing season should be more informative.

Spiraea clearly does best above the first slope break above the flatter marsh surface. While it prefers zones that are not too dry, it does not survive in ponded water. Planted soft rush did best in the same zones as naturally seeded soft rush. This zone is above the most often inundated areas. The soft rush that came in naturally is so successful (at least as of 2011) it is not clear what would be gained by planting soft rush in that habitat.

Figure 95. *Tubed willow in the foreground at Tamara Quays.*

Noxious Weed Control, continued

The most abundant noxious weeds are reed canary grass (Phalaris arundinaceae), English ivy (Hedera helix), scotch broom (Cytisis scoparius) and Himalayan blackberry (Rubus discolor). Each of them presents a long-term challenge. Large-scale use of herbicides was not an option at either site.

Reed Canary Grass

Reed canary grass is a tall, fast-growing rhizomatous perennial grass. It can form monospecific stands and it spreads by roots and seeds. The root mat forms a dense, thick sod. There are several negative ecological impacts of reed canary grass in wetlands. These include the reduction of native plant diversity due to the formation of monoculture stands and disturbance to habitat and food availability to animals. The Pacific Ecological Institute, located in Seattle, Washington, claims reed canary grass can lower dissolved oxygen levels in streams as it dies, accumulates and decomposes. Reed canary grass had taken over the marsh areas of Tamara Quays and Pixieland and created a monoculture. Several methods have been tried to reduce and control the population.

At Tamara Quays, approximately a quarter to a third of the fill removed from the restored marsh areas was reed canary grass sod *(Figures 96 and 97)*. As the earthwork began in the summer of 2009, it quickly became evident that disposing of the sod would be a problem. We learned if it was taken off site, it would have to be disposed of in a landfill that could handle hazardous waste. The cost to do this, approximately $80,000, was prohibitive. We sought advice from other wetland restoration specialists. The solution was to pile it in a mound in the upland meadow area adjacent to the trailer park where the septic system had been. Then it was covered with landscape cloth. Early in the following winter, it quickly became apparent that stakes, sandbags and chunks of large logs were not sufficient to hold down the cloth in a windy area. In the fall of 2010 the whole mound with the landscape cloth was covered with approximately six inches of mulch. In the future, the mound will be planted with native trees to shade out the grass.

Based on observations at Tamara Quays, tufted hair grass (*Deschampsia cespitosa*) that was seeded in, and soft rush (*Juncus effusus*) that came in on its own from the adjacent reference marsh, appear to be very competitive with reed canary grass after the second year in the tidally inundated marsh areas. The soft rush (Juncus effusus) at Tamara Quays and Pixieland is a non-native subspecies that came in on its own. When we plant we'll use tufted hair grass (*Deschampsia cespitosa*). Willow will likely continue to out compete the non-native species along the edge of the tidal flooding.

Figure 96. *Reed canary grass mound after the first winter. The grass is beginning to sprout in between the sheets of landscape cloth.*

Figure 97. *Reed canary grass mound after the second winter. The layer of mulch has successfully held down the landscape cloth.*

At Pixieland two other approaches were tried. In the marsh area that had not been developed, and therefore had not been graded, we tried mowing the grass prior to the development of the seed heads. The intent was to prevent seed production for the year and slow down the spread of grass into areas that were or would be disturbed. Unfortunately, we had a very wet spring and the marsh area was still saturated in late May when the mowing took place. A large excavator with a mowing attachment was used. This caused rutting across this area of the marsh and the seed head development was slowed, but not prevented.

The second method installed large areas of black landscape cloth on an area of marsh which had been graded the year before to inhibit the recolonization of reed canary grass. The cloth was laid down and staked into place with bamboo stakes that were placed at 45 degree angles and formed a vertical "X". This method has pros and cons. The positive side is it that it can inhibit the growth and reestablishment of the reed canary grass. On the negative side it also inhibits the introduction of native plants. Additionally, the bamboo stakes rotted, leaving the cloth vulnerable to movement during winter storms where winds can reach 30-40 mph. Realizing the cloth was at risk of moving into areas where it wasn't wanted, it was removed in the late fall with the intent of reinstalling it in the spring.

Test plots comparing the effectiveness of using landscape cloth versus planting native species to compete with the reed canary grass have been installed at the Pixieland marsh. Treatments being compared include weed cloth only (spring application, fall/winter removal), competitive planting with willow and competitive planting with willows and marsh graminoids. The Salmon Drift Watershed Council has a contract with a tidal wetland specialist to install, monitor and report on the results of these test plots. Results will be compiled over the next five years.

Himalayan Blackberries

Blackberries had overtaken the upland areas of both Tamara Quays and Pixieland. Initial treatments involved the use of heavy equipment to clear the land. At Tamara Quay the upland meadow areas, which had become a sea of blackberry vines, were mowed and disked up to twice a year, usually once in the spring and once in the fall. The disking needs to be done at a depth of at least eight inches in order to disrupt the root crowns. One disking was done at a four inch depth and was not effective. The blackberries were quickly killed in the lowlands that became inundated after the dikes were removed.

At Pixieland, blackberries were cleared with an excavator, front-end loader and bulldozer and piled and burned. The watershed council has led the ongoing efforts to keep the blackberry vines under control.

At both sites eradication efforts, mainly through manual methods of cutting vines and digging out roots, have had to be consistent and persistent to keep the blackberries in check. Keeping the blackberries under control will be an ongoing effort for many years. In areas not replanted with trees, a major effort to eliminate and control blackberries is needed for approximately five years, followed by several years of moderate effort. Some level of ongoing maintenance is needed to prevent the blackberries from retaking the site.

Scotch Broom

The dike and dam at Tamara Quays were covered with scotch broom and several large patches were also present at Pixieland. Scotch broom seeds can stay viable for many years. Initial efforts included mechanical removal with heavy equipment, piling and burning. Ongoing efforts involve pulling the plants. Like blackberries, scotch broom died out in the areas inundated after the earthwork was completed. Pulling the scotch broom when it's a small plant is the best option for ongoing control.

Japanese Knotweed

An isolated patch of knotweed was found on the banks of the Salmon River at Pixieland. There is a source upstream of the estuary, so infestation will remain a threat. The patch was treated by cutting it down and injecting herbicide into the stems. Vigilance and follow-up control will be needed to make sure it doesn't return.

Getting Vegetation Work Accomplished

A variety of crews were hired for planting and weed control. The Salmon Drift Watershed Council received grants to hire displaced commercial fishermen whose livelihoods had been adversely affected by salmon fishing restrictions. The fishermen crew has been a steadfast source of dedicated workers who take pride and ownership in the work *(Figures 99 and 100)*. They have planted trees, installed the landscape cloth and tackled the blackberries and scotch broom.

For projects requiring just one or two days of work, we also enlisted the county sheriff's parole crew. Finally, the local high school had a natural resources student group who did some volunteer work. Their participation gave the watershed council a chance to interact with the community and do some environmental education. The watershed council also organized a couple of volunteer days and invited the local citizens to enjoy a day at the sites and pull weeds or spread mulch.

Vegetation Management

Communication between the team members who are creating and implementing a planting plan and the project managers who are implementing the earthwork is vital. Often the plans for the earthwork have to change. This results in a finished landscape that may be different from the one initially envisioned. An as-built survey is critical information for planting after the earthwork is completed. As an example, the elevations of the completed ditch and dike removal in the southwest corner of Pixieland were lower and wetter than initially anticipated. Areas initially thought to be suitable for trees may be better suited for marsh habitat.

Another consideration is that the vegetation will change rapidly during the first two to three years after the earthwork is completed. In areas immediately inundated by tidal flow, native plant seeds were brought into the newly created marsh surface, with rapid colonization by *Deschampsia cespitosa* and other marsh species. It may take two to three years to see any stabilization in the suite of plants.

Browsing by elk *(Figure 98)* and deer should also be considered. Trees, especially cedar seedlings, may be heavily browsed and may need to be protected with wire cages until they are established. In areas that will be planted with native trees and shrubs, don't spend money on planting native grasses. If a cover crop is needed for erosion control, consider using annual rye, or something equivalent. Native plants that will readily seed into the site do not need to be purchased and planted. Alder is a good example. Mature alder trees were present on both sites adjacent to disturbed areas, and have seeded in on their own.

Another consideration is that more willow is always needed than initially planned. Identify good sources of willow cuttings ahead of time.

If long-term weed control isn't feasible, especially for the woody weeds, plant closely spaced trees to provide dense shade. Also, plan on long-term control affects, (around five to 10 years), for woody noxious weeds such as blackberries and scotch broom. Continue to monitor and walk around the sites, noting the need for weed control or replanting. It would have been useful to have soil and water salinity data prior to planting since salinity may inhibit some of the weeds.

Figure 98. *Resident elk herd pulling up planted spruce trees. This site required additional maintenance to ensure planting success due to the elk.*

Appendix: Citations

Figure 99. *Vegetation Transect September 2014 at Crowley Creek.*

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Figure 100. *The old entrance road to Tamara Quays after restoration. Protected plantings in elk enclosure and tubed willow adjacent to restored marsh. February, 2010.*

Appendix: Partners/Contributors

Partner	Contribution
USFS Siuslaw National Forest	Project Management, Project Implementation, Engineering/Design
Salmon Drift Creek Watershed Council	Project Management, Project Implementation, Project Administration
Oregon Watershed Enhancement Board	Funder & Champion
United States Fish & Wildlife Service	Funder
Oregon Department of State Lands	Funder, Effectiveness Monitoring
Hire the Fishermen Crews	Project Implementation
Oregon Department of Fish & Wildlife	Research
The Nature Conservancy	Technical Advisor, Community Engagement
Sitka Center for Art & Ecology	Community Engagement
Westwind Stewardship Group	Community Engagement
Nisqually National Estuarine Reserve	Technical Advisor
The Oregon State Police Fish and Wildlife Division	Safety
Oregon Department of Transportation	Funder, Research
Greenpoint Consulting	Effectiveness Monitoring
Oregon State University Sea Grant	Research
National Oceanic & Atmospheric Administration	Research
Environmental Protection Agency	Research
South Slough National Estuarine Research Reserve	Technical Advisor
University of Washington	Research
Western Oregon University	Research
Lincoln Soil &Water Conservation District	Community Engagement
Sheet Metal Solutions, Inc. Oregon Powder Coating R3 Engraving and Signs	Pixieland Rail Line Collaboration Award
Lincoln County Planning	Permitting
Adriene Koett-Cronn	Editing Services in AP Style
Heidi B. Lewis	Graphic Design

Appendix: Tamara Quays

Work Accomplished in 2007

Work done in 2007 focused on cleaning up the site, removing some of the infrastructure and opening the rusted tide gate.

- Removed concrete trailer pads.
- Filled in and properly decommissioned the septic tank.
- Removed the sliding gate on the inlet of the tide gate that was causing Kingfisher Lake to back up and flood. This allowed Kingfisher Lake to drain and was the start of the hydrologic restoration.

Work Accomplished in 2008

Clean-up work in 2008 focused on removing the underground utilities. The main project in 2008 involved replacing the undersized culvert at the head of tide on North Fraser Road with a culvert wider than the bankful width of Rowdy Creek. This allowed aquatic organisms access to the upper portion of Rowdy Creek.

- Removed .85 acres of asphalt from roads
- Removed 1,755 linear feet of buried cables, wire and utility boxes.
- Filled five manholes and vaults.
- Removed water tank (35 feet high by 20 feet wide).
- Removed two dump trucks full of garbage.
- Removed 60 foot long water line that crossed Rowdy Creek.
- Replaced the undersized culverts on Rowdy Creek at Fraser Road with a 20' wide fish-passage culvert.

Work Accomplished in 2009

The majority of the work on Tamara Quays was done in 2009. The marsh surface adjacent to Rowdy Creek was exposed for the first time since the late 1960s. Fill material approximately three feet deep was removed. The dikes, dam and tide gate were removed, connecting this area to the rest of the estuary. Ditches were filled in.

In addition to the earthwork, two wells were decommissioned and a power pole and power line were relocated.

- Removed 2,000 cubic yards of reed canary grass sod and placed it in the back meadow. It was covered with black landscape cloth to inhibit growth and planted with native trees.
- Moved and rearranged 27,500 cubic yards of dirt. Fill material was removed from the surface of the marsh and from the dikes. It was placed on recontoured hill slopes adjacent to the marsh surface and in the uplands to the east of the Rowdy Creek marsh.
- Filled 2,010 linear feet of ditches.
- Removed 2,210 linear feet of dike and dam.
- Removed fill from 4.3 acres of marsh which had been converted to the trailer park sites and graded it to match the elevation of the reference marsh.
- Restored 12.7 acres to estuary wetlands.
- Placed wood along the shore of Kingfisher Lake for habitat enhancement.
- Built a land bridge log jam between the eastern shore of Kingfisher Lake and the island for habitat enhancement.
- Built a log jam at the northwest corner of the project area where the western ditch meets the estuary for habitat enhancement.
- Placed large wood along the western edge of the marsh for habitat enhancement.
- Removed fill from the top of the island and graded it to the elevation of the reference marsh.
- Removed two dump truck loads of old PVC pipe and other infrastructure and took it to the landfill.
- Assisted Pacific Power and the well decommissioning contractors gain access to their work sites.
- Pacific Power moved a power pole from the area that was restored to tidal wetlands and replaced it with two power poles along Fraser Road.
- Decommissioned the road going up the hill to the well sites.
- Dug tidal channels in the old trailer park to resemble the historic tidal channels.
- Dug channels to connect the slope drainage to the marsh across the filled ditches.
- Removed the culvert and tide gate.
- Graded the side slopes to match the original topography.
- Placed logs and boulders to discourage illegal entry by four wheel drive vehicles.
- Installed a new, heavier gate to discourage illegal entry.

Rowdy Creek is now free flowing from the headwaters above North Fraser Road to its confluence with Salmon River. The area that was separated from the rest of the estuary by a dam and tide gate is now connected to tidal ebb and flow. Figures 101-110 show the work in progress.

Figure 101. *New Rowdy Creek culvert, built in 2008.*

Figure 102. *The dike and ditch on the west side of the Tamara Quays site prior to earthwork.*

Figure 103. *Work in progress on the dike and ditch removal. The tracked dump truck is transporting fill material that will be placed in the ditch.*

Figure 104. *Placing large woody material along the edge of Kingfisher Lake for habitat enhancement.*

Figure 105. *The exposed PVC pipe marks the original marsh elevation. Fill removal is in progress in the background.*

Appendix: Tamara Quays

Figure 106. *Removing fill from the buried marsh floor. Note the dried grass that was uncovered in the foreground, confirms the original marsh surface has been uncovered.*

Figure 107. *Using rod and laser level to check elevation levels during grading.*

Figure 108. *RA laser level eye was mounted on the blade of the bulldozer. This allowed for precise grading in an efficient manner.*

Figure 109. *Removing the culvert at the tide gate.*

Figure 110. *Shaping the stream banks after the culvert and tide gate were removed.*

Figure 110. *Rowdy Creek after lower tide gate has been removed.*

Designing the New Stream Channels:

Three new stream channels were designed for the Pixieland site. Two were relatively small and one was a new location for the Fraser Creek mainstem. The original location of the Fraser Creek channel and it's tributaries were mapped from historic aerial photos. The new channels could not be recreated in their original locations, however, because sections of the highway interchange built in 1961 now occupied the area where there had been upstream reaches of Fraser Creek. The new channel location was moved farther out into the central area of the marsh to minimize the possibility of the new stream channel affecting the highway road prism in the future.

The process of designing the new mainstem location was iterative. The first location considered, based on the LiDAR mapping, is shown by yellow dots on Figures 112 and 113. Remnants of the original Fraser Creek channel and tributaries still exist. These remnants were used as reference templates. Cross sections to determine the width and depth of the original channels. After the on-the-ground survey was completed, the gradient of the stream channel from the Highway 18 culvert to the marsh surface was calculated at 1.1%. A gradient of that slope on fine-grained material raised concerns about head cutting up to the culvert. Also, the main stem channel would be wider than the existing tributary channel emptying into it. There was concern the constriction could cause problems in the future evolution of the channel. The upstream portion of the mainstem was moved east where ground below the culvert was higher and the slope could be reduced to 0.5% for about one third of the channel directly downstream from Highway 18.

The second iteration crossed back and forth across an old roadbed extending into the marsh and was south of a big willow patch (yellow solid line). After the trees were cleared from the roadbed in preparation for removing the road fill, it was discovered the second channel location came within a few feet of the upstream end of two small tributary channels. To prevent the new channel from diverting into the existing smaller tributary channels, the planned location of the main stem was moved once more to a location north of the willow patch, shown by the red line.

This third iteration had the following advantages. First, it is north of a willow patch which could instantly provide shade and cover. Second, the stream channel length was increased along with the amount of potential habitat. The first iteration of the mainstem channel (yellow dots on *Figures 111 and 112*) was reduced in width and left as the tributary channel that drains a ditch relief culvert under Highway 18.

In 2010, when the marsh surface was graded, a drainage channel was not built in the northern portion of the marsh (area with the channel represented by the dotted red line, *Figures 111 and 112*). Drainage began to develop on its own the first winter and was connecting to the Fraser Creek ditch. Eventually, when a bridge is built on U.S. Highway 101 to cross the original Fraser Creek channel location, this ditch will be filled. We did not want a drainage network developing that connected directly to the ditch since it would have to be reconfigured at a later date. A new, small drainage channel (dotted red line on *Figures 111 and 112*) was designed and constructed. It connects to an existing tributary channel which will be left in place.

The two reference cross sections for the mainstem had an average width of 10 feet, and an average depth of 1.5 feet. The final design specifications for the mainstem were eight feet wide and about two feet deep. Depth varied depending on the microtopography. The gradient for the first 360 feet of constructed channel was 0.5%. The last 700 feet had a gradient of 0.2%.

The tributary channel connected to the drainage ditch culvert under Highway 18 was 640 feet long, two feet wide and an average of 1.5 feet deep. For the first 265 feet from the culvert outlet to the marsh floor, the gradient is 1.0%. For the last 375 feet, the gradient is 0.2%.

The marsh drainage channel to the north was two feet wide, and the depth tapered from approximately two feet deep at the mouth to zero feet at the end. The gradient is 0.29%.

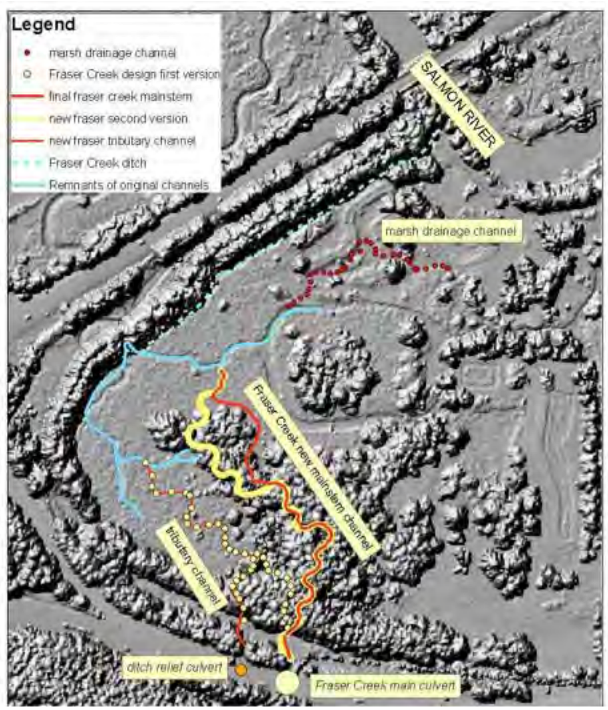


Figure 112

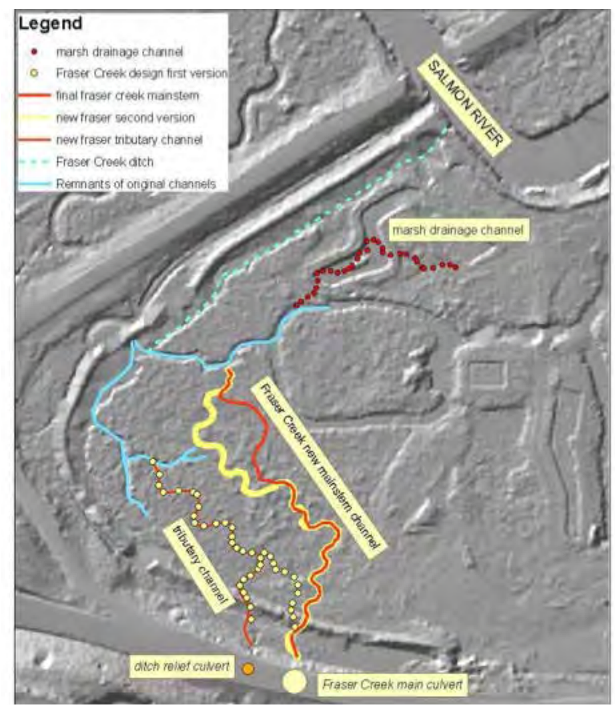


Figure 113

Appendix: Pixieland

Work Accomplished in 2007

The main focus of the 2007 work period was cleaning up the site and clearing the ground surface. This included the following items.

- Cleared at least 30 acres of wall-to-wall blackberries and other invasive non-native vegetation, then put it in piles for burning.
- Removed and recycled over 4,000 cubic yards of asphalt.
- Removed 1,500 cubic yards of concrete from old building foundations, sidewalks and pillars from the log-flume ride. The concrete is considered “clean fill” by Oregon Department of Environmental Quality and was buried on site in the higher elevation area of the old RV park.
- Hauled away several dump truck loads of garbage.

Work Accomplished in 2010

A large part of the earthwork was done in 2010. The interior of the site was the main focus. The fill was removed from the marsh surface and used to fill in the interior ponds. Additional work included the following items.

- Graded and restored eight acres of marsh.
- Removed dike along the Salmon River.
- Moved over 27,000 cubic yards of fill.
- Properly decommissioned three water wells.
- Filled in interior ditches and ponds

Work Accomplished in 2011

The last phase of the earth work was done in 2011. It focused on restoring the hydrology of the area. The dikes and ditches along Highway 18 and U.S. Highway101 were removed and new stream channels were dug for Fraser Creek through the wetland portion of the site. The following items were also accomplished.

- Removed 40 year old spruce trees on dike.
- Removed 2,000 linear feet of dike.
- Filled 2,300 linear feet of ditches.
- Constructed 2,400 linear feet of new, meandering channel.
- Placed approximately 100 spruce logs around the old RV park as future nurse logs.
- Removed the concrete tide gate structure.
- Removed the last asphalt road.

Figure 111.
Highest hits LiDAR image showing the location of the remnant and new stream channels for Fraser Creek.

Figure 112.
Bare earth LiDAR image showing locations considered and built for the new Fraser Creek channel and tributaries.

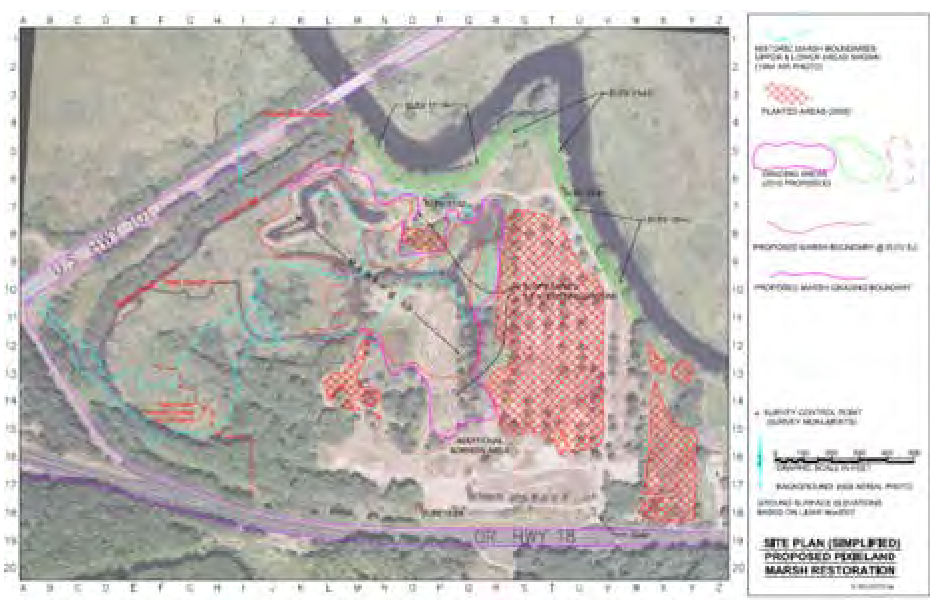


Figure 113.
Simplified grading plan for Pixieland, July 2010.

Figure 114. *The dike along the Salmon River was cleared of vegetation, but is still present in this photo. The U.S. Highway 101 bridge over the Salmon River is in the background and the tide gate house is still standing.*

Figure 115. *The dike has been removed and re-shaped to resemble the natural levee present along other nearby sections of the river. The tide gate house is gone. Woody debris was scattered over the disturbed area.*

Figure 116. *Filling interior ponds.*

Figure 117. *Filling interior ponds.*

Figure 118. *Removing fill from the restored marsh surface, work in progress.*

Figure 119. *Finished marsh surface after the grading was completed. View to the north.*

Appendix: Pixieland

Figure 120

Figure 120. *Photo trio of Pixieland in 1984 showing the Dairy Gold barn on Main Street, the train depot and the whale fountain all in disrepair following 1981 bankruptcy.*

Figure 121

Figure 121. *Pixieland in 1984. Looking Northwest toward Cascade Head in the distance.*

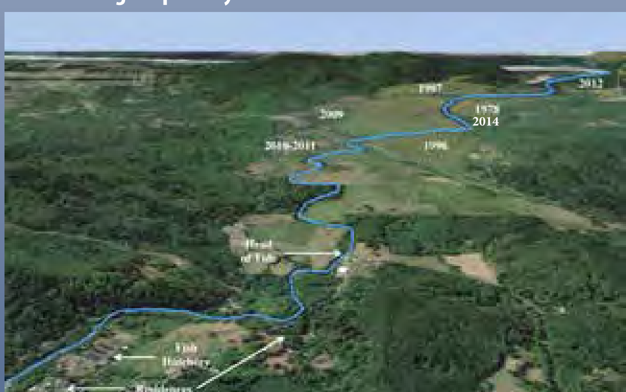
Figure 122

Figure 122. *Main Street, Pixieland just after the restoration 2011.*

Tidal Marsh Restoration

Mitigating the Impacts of Storm and Sea Level Rise

Oblique aerial photo of the Salmon River estuary flown in 2011. The area highlighted in blue depicts the restored flood storage capability of the tidal marshes. Each marsh restoration is identified by the year it was completed.



Google image of the Salmon River estuary in 2013. Blue line represents the Salmon River. Each marsh restoration is identified by the year it was completed. The fish hatchery and the residents upstream have experienced reduced frequency of flooding.

Mean sea-level rise projected on a Salmon River estuary LiDAR image. It is important to understand the image only shows projected mean tide, if the elevated tides are coupled with a large sustained rainfall event the flooded area will increase. Created by Rebecca Flitcroft, PNW Research Station.

Is this the end or, just the beginning…

The intertidal portion of the Salmon River estuary has been impacted by development since the mid-1900s. Tides in this area reach four miles up-river. All but one low marsh system was altered to prevent tidal inflow and control freshwater outflow. Since 1974, however, this 1,900 acre estuary has been given back, incrementally, to the tides. Now the physical restoration is over and the tide has returned.

Why does this restoration matter? What difference will it make?

With nearly the entire estuary now restored to a natural, historic tidal regime, approximately 2,400 acre/feet of flood storage is open. Results indicate the reestablished tidal channels and marsh area will provide increased flood capacity during peak tides that are coupled with rainfall events. For residential properties in the area, this means there will be less up stream flooding. Climate change models project increased frequency and intensity of the wet season. This, combined with an anticipated increase in tides, poses a real flood danger to many low-lying coastal areas. The Salmon River estuary restoration can serve as a model for efforts to restore vital tidal systems around the nation and world.