SATSOP RIVER INVESTMENT PLAN

GRAYS HARBOR COUNTY 1854

CONSERVATION DISTRICTS OF WASHINGTON STATE

Grays Harbor Conservation District

your window to healthy lands

January 2019

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ACKNOWLEDGMENTS

Thank you to the many **community members** who met with the project team individually and participated in the community meetings. The people living in the community along the Satsop River are a strong, passionate, and collaborative group and Grays Harbor County looks forward to working together to put this plan into action.

The County would also like to thank the Grays Harbor Conservation District for their participation in this effort, their commitment to working with landowners along the Satsop River, and their leadership in implementing projects on the river.

Many thanks to those who participated in the Advisory Group.

- Scott Boettcher, Chehalis River Basin Flood Authority
- Michelle Cramer, Washington State Department of Fish & Wildlife
- Kevin Dahl, Washington State Department of Transportation
- Larry Karpack, Watershed Science & Engineering
- Allen Lebovitz, Washington State Department of Natural Resources
- Rick Mraz, Washington State Department of Ecology
- Bethany Nickison, U.S. Army Corps of Engineers
- Vickie Raines, Grays Harbor County/Board of County Commissioners
- Steve Schmitz, KPFF Consulting Engineers
- Rick Schwartz, Washington State Department of Natural Resources
- Alissa Shay, Port of Grays Harbor
- Amy Spoon, Washington State Department of Fish & Wildlife
- Anthony Waldrop, Grays Harbor Conservation District
- Rob Wilson, Grays Harbor County

This plan was prepared by **Maul Foster & Alongi**.

EXECUTIVE SUMMARY

The Satsop River Valley is a vital and important area in Grays Harbor and Mason Counties. The landscape supports multi-generational agriculture businesses, commercial forestry, rural residences, and public parks. The Satsop River Valley is also an economic crossroads, with State Route 12 connecting coastal communities to Puget Sound and Keys Road providing access to the Satsop Business Park, which supports over 400 jobs. The Satsop River also provides habitat for salmon and steelhead.

Communities in the Satsop River Valley are challenged by dramatic migration of the river across its floodplain and frequent flooding. The Satsop is a powerful river, dropping steeply down from its headwaters in the Olympic Mountains to a flat floodplain in its lower valley. The river has a history of migrating widely and at times suddenly across its floodplain.

Erosion of river banks, and avulsions, where the river dramatically shifts its channel during a flood event have caused loss of tens of acres of productive agricultural land in recent years. It also threatens public infrastructure including Keys Road. Populations of salmon, steelhead and other fish and wildlife species are also struggling to respond to impacts from decades of habitat degradation.

Grays Harbor County, in partnership with the Grays Harbor Conservation District and supported by funding from the Chehalis River Basin Flood Authority, has developed this Investment Plan through a collaborative effort with public agencies and private landowners to develop shared goals and a prioritized set of projects to reduce risk of erosion while enhancing habitat for fish and wildlife.

Project Goals

A set of common goals was established at the beginning of the planning process and reviewed by a public agency advisory committee and local community members

- Goal 1: Protect public and private infrastructure and agricultural lands from bank erosion.
- Goal 2: Improve floodplain connectivity to spread flood flows throughout the floodplain and restore side-channel and off-channel habitats for anadromous and resident fish, and wildlife.
- Goal 3: Reduce flood hazards and manage flood risk in the project area.
- Goal 4: Protect and maintain recreational opportunities.

Project team members meet with Jose Torres to discuss flooding challenges and concerns on his property east of Keys Road.

Investment Plan

The Investment Plan provides a road map indicating which projects should be implemented on the Satsop River in order to address the key issues of erosion, flooding, and loss of farm land.

Table 2. Investment Plan

PROJECT (LEAD AGENCY)	NEAR-TERM 2019-2020	MEDIUM-TERM 2021-2025	LONG-TERM 2026-2045	FUNDING SOURCE
Large Woody Debris in Upper Watershed (GHCD) *Slow river velocity to reduce erosion and enhance habitat*	Design & Construct Pilot *$350K*	Design & Construct (3-5 mi) *$425K - 725K*	Design & Construct (15-20 mi) *$2 M - $3 M*	WQ Grants, WCRI, CRBFA
Engineered Log Jams on East Fork of Satsop River (GHCD) *Bank stabilization and habitat enhancement*	Design & Construct *$6.8 M*			Chehalis Basin Strategy
Keys Road Soft Armoring (GHC) *Protection of key public infrastructure while minimizing environmental impact*	Design *$375K*	Construction *$2 M - $2.5 M*	Maintain & Monitor *$50K*	CRBFA, GHC
Infrastructure and Long-Term Asset Planning (GHC) *Evaluate options for changes in coordination with eventual bridge replacement*			Plan for and Implement Modifications *$TBD*	GHC
Engineered Log Jams on Lower Satsop River (GHCD) *Bank stabilization and habitat enhancement*	Design *$50K - $75K*	Construct *$150K - $250K*		WCRI, WWRP, CRBFA, FbD
Gravel Ponds, Phase 1 (WDFW) *Increase floodplain connectivity and enhance habitat*	Construct *$1 M*			WCRI
Gravel Ponds, Phase 2 (WDFW) *Increase floodplain connectivity and enhance habitat*		Construct *$1.7 M*		WCRI
Engineered Log Jams - Other Locations (GHCD) *Address bank erosion to protect farm land and infrastructure, including bridges*		Feasibility Study *$150K*		CRBFA, FbD, WCRI, WWRP, SRFB
Land Conservation (Multiple Agencies) *Increase flood plain connectivity and enhance habitat*		As Opportunities Arise with Willing Sellers		CRBFA, FbD, WCRI, WWRP, SRFB

TABLE KEY

Location in the Watershed

- *Upper watershed*
- *Middle watershed*
- *Lower watershed*
- *Across entire watershed*

Acronyms

CRBFA: Chehalis River Basin Flood Authority
FbD: Floodplains by Design
GHC: Grays Harbor County
GHCD: Grays Harbor Conservation District
SRFB: Salmon Recovery Funding Board
WCRI: Washington Coast Restoration Initiative
WDFW: Washington State Department of Fish & Wildlife
WQ Grants: Coordinated Water Quality Grants
WWRP: Washington Wildlife and Recreation Program

INTRODUCTION

CHAPTER OVERVIEW

The Investment Plan builds on previous efforts to address erosion, flooding, and habitat impacts in the Satsop River. This opening section provides context for the Satsop River Investment Plan and describes the project purpose, goals, and planning process.

The Satsop River Valley is a vital and important area in Grays Harbor and Mason Counties. The valley is home to multi-generational families of farmers and ranchers, growing corn, hay, and pumpkins and raising dairy cows and beef cattle.

The Lower Satsop River Valley is also an economic crossroads, with State Route 12 connecting coastal communities to Puget Sound and Keys Road providing access to the Satsop Business Park, which supports over 400 jobs.

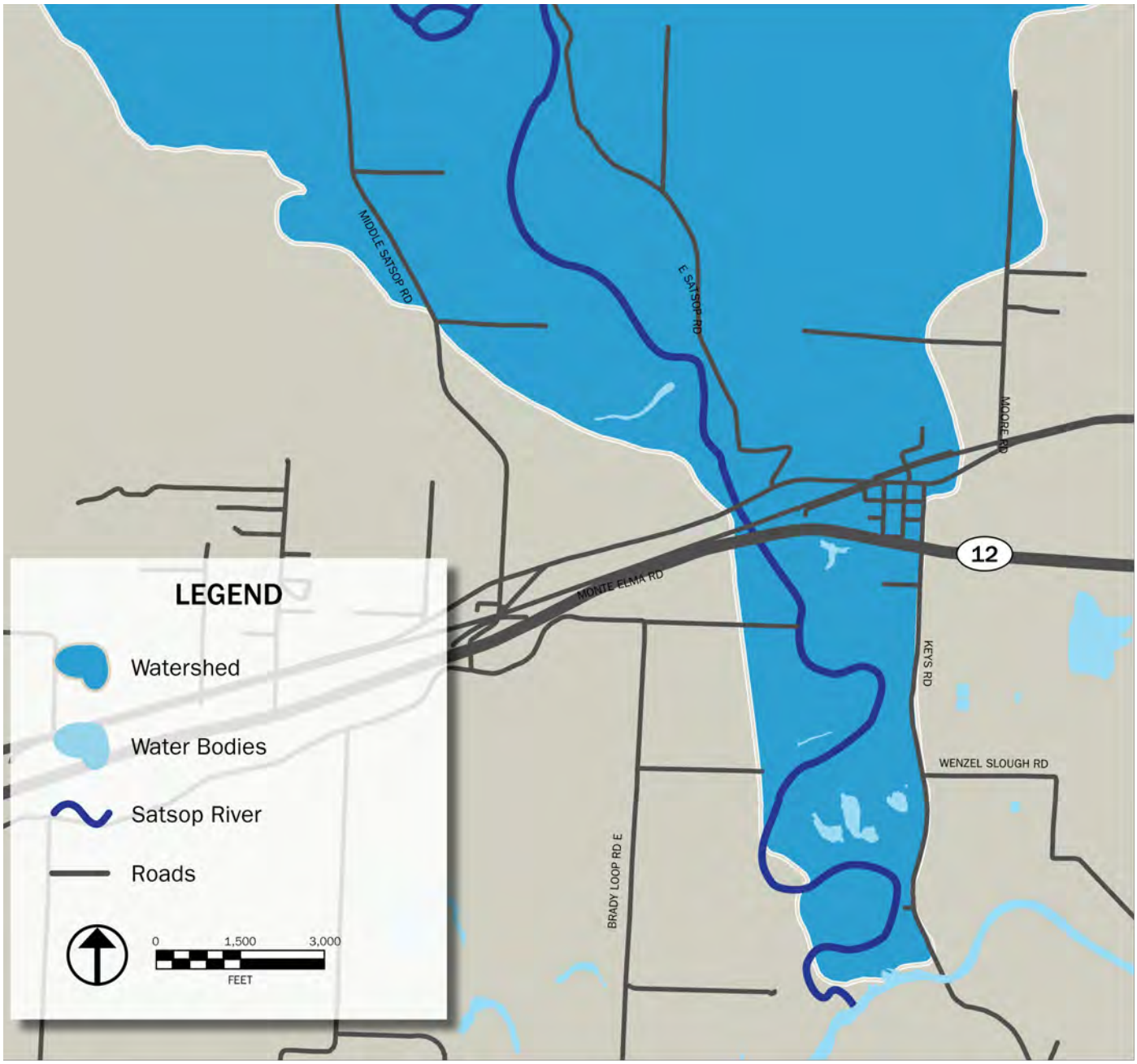
The Satsop River also provides habitat for salmon and steelhead. The Satsop basin contributes approximately 33% of fall-run Chinook, 33% of winter-run steelhead, and 18% of the coho population of the entire Chehalis River Basin upstream of the Wishkah River.

This area has historically developed around the Satsop River and adapted to its natural processes of flooding and migration. In recent years, concerns about bank erosion and migration of the river channel have increased. The river has moved up to 100 feet per year in certain locations. This migration has eroded tens of acres of farmland and is putting the long-term viability of family-owned farms and ranches at risk. Critical infrastructure including Keys Road, a main connection to the Satsop Business Park also faces risk of erosion.

For more than a decade, studies have been conducted and plans developed to try to reduce erosion and flood risk. Individual property owners have taken actions to try to protect their land. No silver bullet solution has been identified. There are multiple drivers of flooding and erosion and multiple areas that are impacted. Projects that prevent erosion in one place may make it worse in another. Projects that may reduce flooding may also impact existing infrastructure or habitat. The different perspectives of various stakeholders have often come into conflict.

Despite these challenges, progress is being made. Funding has been provided by Washington State through the Chehalis River Basin Flood Authority and other programs to support planning and implementation of projects to reduce erosion and flood risk as well as enhancing natural habitat. In 2018, Grays Harbor County convened stakeholders together to coordinate efforts and develop a long-term plan for the Lower Satsop River. The County was supported in this effort by the Grays Harbor Conservation District (GHCD) to increase engagement of local property owners.

Figure 1. Project Location



Project Purpose

The purpose of this planning effort is to build consensus around an investment plan for the Lower Satsop River that achieves shared goals. The investment plan includes a prioritized list of projects that address the different interests of the various stakeholders and includes short-term and long-term phasing and funding strategies.

Project Goals

A set of common goals was established at the beginning of the planning process and reviewed by a public agency advisory committee and local community members

- Goal 1: Protect public and private infrastructure and agricultural lands from bank erosion.
- Goal 2: Improve floodplain connectivity to spread flood flows throughout the floodplain and restore side-channel and off-channel habitats for anadromous and resident fish, and wildlife.
- Goal 3: Reduce flood hazards and manage flood risk in the project area.
- Goal 4: Protect and maintain recreational opportunities.

Figure 2. Planning Process

Planning Process

The Investment Plan builds on previous studies and employed a collaborative process to engage local community members and public agency representatives to find common ground and shared priorities. The planning process was organized around five major steps (See Figure 2):

- Build a shared understanding of the causes and symptoms of erosion, flooding, and fish habitat degradation. Develop a set of common goals.
- Identify a broad set of potential projects and programmatic solutions to addressing challenges and achieving the goals.
- Evaluate the feasibility and benefits of the potential solutions.
- Create a list of priority actions that can be completed in the short-, mid-, and long- term that will address the issues and achieve the goals.
- Plan for implementation by identifying roles and responsibilities for partners, timeline for action, and potential funding sources.

Community and Stakeholder Engagement Summary

The community living and working along the Satsop River has been engaged in this discussion for a long time. The purpose of this project was not to do another technical study of the river, but to work with the community and regulatory agencies to identify feasible solutions, establish priorities, and develop an investment plan that will help the community start implementing projects that have agency support and a clear path forward.

In order to engage both the local community and public agencies, the project team conducted parallel processes of identifying issues, brainstorming solutions, and prioritizing the options.

The project team walks through Terry Willis' farm to see first hand and talk to Terry about the impacts of the Satsop River's migration.

Credit for all photos to Jones Photo Historical Collection.

Loggers posing near Brady after having loaded 67 railroad cars and winning a bet with the boss who doubted that they could (Labor Day, 1923).

Two loggers taking down a tree in Grays Harbor County (1890)

Satsop Business Park celebrating the lease expansion of Overstock.com's call center bringing new jobs to the region (2017).

Flooding (1949) at the Buford Goeres farm south of Satsop. A portion of this land is now operated by Jose Torres.

EXISTING CONDITIONS

CHAPTER OVERVIEW

This chapter describes the physical and biological conditions of the Satsop River watershed, including geology, climate, land use, river dynamics, and fish and wildlife habitat. The chapter concludes with a discussion of how these conditions support an understanding of the drivers of flooding, erosion, and habitat degradation.

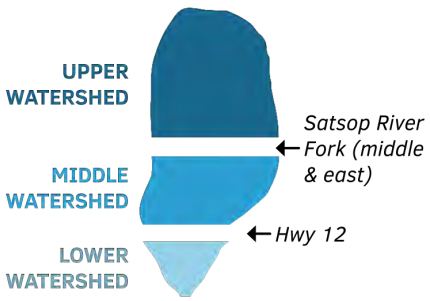
Geologic Setting

The geology of the Satsop River Watershed is defined by mountains, valleys, and a history of glaciation. Most of the bedrock in the Satsop basin is overlain by glacial deposits.[1] About 20,000 years ago the Puget Lobe of the continental ice sheet covered some of the smaller sub-basins of the East, Middle, and West Forks of the Satsop River, depositing huge volumes of gravel-rich sediment from meltwater channels. Sub-basins not influenced by the continental glacier received extensive deposits of outwash from alpine glaciers. The alpine glacial material is derived from local bedrock and consists largely of sandstone and other sedimentary rock that breaks down quickly, making it a poor source of gravel but a significant source of sand and finer material. The abundance of glacial material makes the Satsop River one of the highest sediment-producing rivers on the Olympic Peninsula.

WHAT IS A WATERSHED?

The Satsop River Watershed spans the border of Grays Harbor and Mason Counties.

The watershed includes the area of land where all of the water drains to and collects in the Satsop River.



Potential solutions in Satsop River Watershed can be divided into three separate areas: the upper, middle, and lower watershed.

A watershed includes the area of land where all of the water drains to and collects in a river. The Satsop River has a watershed of about 300 square miles that includes portions of Grays Harbor and Mason Counties. The river originates in the Olympic Mountains with three tributaries, the East, Middle, and West Fork Satsop Rivers. Below the forks, the mainstem Satsop River flows through a broad, flat valley. The Satsop River drains to the Chehalis River, which is tidally influenced at the confluence.

Climate

The climate of the Satsop River watershed is characterized by relatively warm, wet winters and cool, dry summers. Due to the watershed's location relative to the Olympic Mountains, average annual precipitation in the basin ranges from less than 70 inches per year near the town of Satsop to about 180 inches per year in headwater areas.

The effects of climate change are becoming apparent throughout the Pacific Northwest. Several studies have recently been conducted to forecast likely impacts of climate change along the Washington coast and around Grays Harbor. The University of Washington's Climate Impacts Group recently conducted an evaluation of projected climate change impacts in the Puget Sound region[2] and a study of the potential effects of climate change specifically on the Chehalis River Basin[3]. Key findings of the studies are summarized below.

Key Findings

- Increased warming of the region over the 20th and 21st centuries is expected to be a key driver of precipitation change in Washington State, particularly surrounding the Washington coast. Warming for the twenty-first century is expected to be double that experienced in the twentieth century. Regional warming is expected to cause an increase in severity and frequency of heavy rainfall events in a given year. The University of Washington report estimates that there could be up to an approximately 25% increase in projected annual precipitation in the Chehalis River Basin by 2060.
- Warmer regional temperatures will additionally cause an increased proportion of precipitation to fall as rainfall versus snow. The University of Washington study predicts that increased rainfall and decreased snowfall will lead to an approximately 80% decrease in snowpack in the Chehalis Basin by 2060. Since snow retains water from fall and winter storms, this shift from snow to rain is projected to result in increased risk of flooding and landslides.
- Stream flows are projected to be affected by changes in temperature and precipitation. Studies generally show an increase in winter stream base flow and decrease in summer stream base flow. The increased flow in winter is in response to higher intensity and more frequent rain events and decrease in snow pack. Lower summer flows are related to decreased precipitation in the summer and increases in evaporation associated with higher temperatures.

The landscape around the Satsop River is highly vegetated. The power of the Satsop River to erode can be seen on this steep bank with corn growing just a few feet away

[1]Collins, B.D., and T. Dunne, Gravel Transport, Gravel Harvesting, and Channel-Bed Degradation in Rivers Draining the Southern Olympic Mountains, Washington, USA. Environmental Geology and Water Sciences 3:213-224, 1989

[2]Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

[3]Mauger, G.S., S.-Y. Lee, C. Bandaragoda, Y. Serra, J.S. Won, 2016. Effect of Climate Change on the Hydrology of the Chehalis Basin. Report prepared for Anchor QEA, LLC. Climate Impacts Group, University of Washington, Seattle.

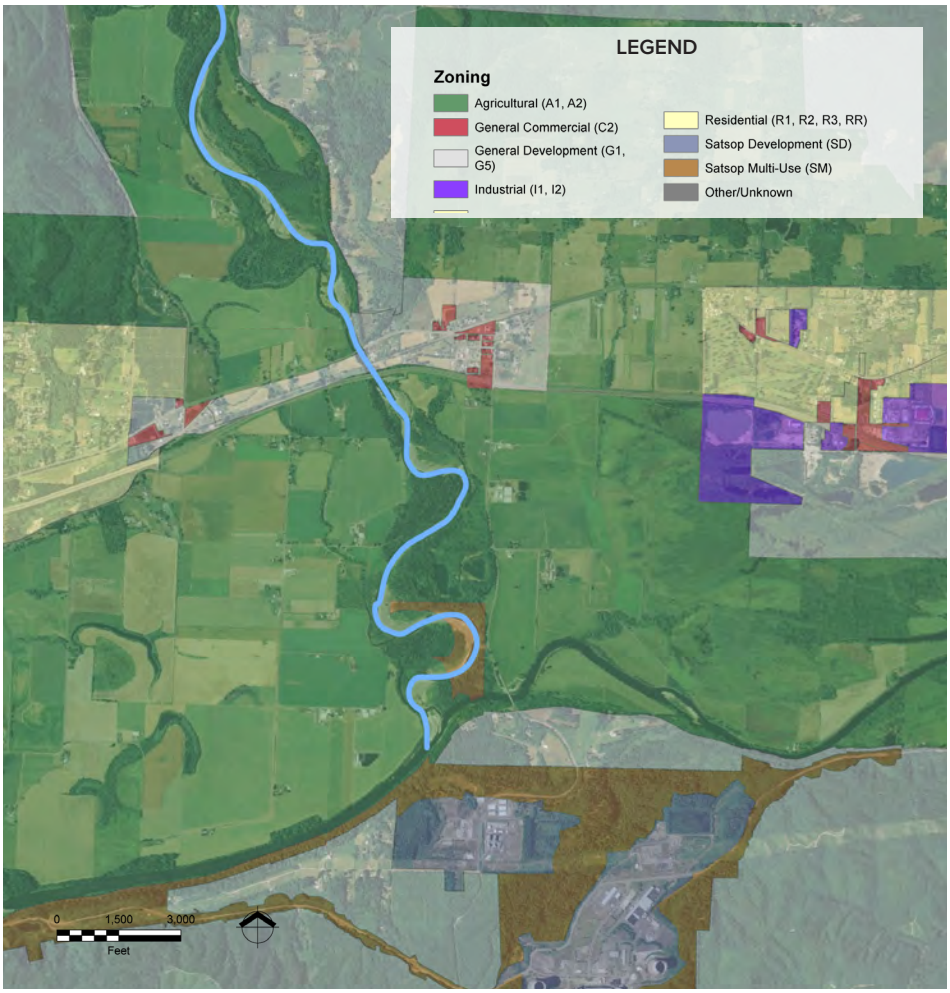
Land Use and Development

The Chehalis Basin and the Satsop River have been inhabited for thousands of years by the ancestors of the Quinault Indian Nation and the Confederated Tribes of the Chehalis Reservation. The first permanent European settlers in Grays Harbor County arrived around the 1850s. Within a few decades of European settlement, the rich natural resources supported growth in farms, timber harvest, lumber mills, salmon fishing, and canning. However, in the 1920s, the timber industry began a long, slow decline. Most of the timber had been cut from private land, and by 1975, much of the local capacity to process timber had declined significantly. Timber harvest was further reduced in the 1980s and 1990s after the Northern Spotted Owl was listed as threatened under the Endangered Species Act.

Early logging techniques dramatically altered the landscape and condition of the river.[4] Logging removed the old growth forest, including trees in the riparian areas. The logged-over land was typically burned without replanting, which lead to regrowth dominated by deciduous trees, which provide less stability to the soils than conifers. A network of logging roads was constructed, which contributed to erosion and sediment loading to streams. Splash dams were constructed to facilitate movement of logs downstream, which led to additional channel impacts. Large woody debris was cleared from streams, which reduced habitat complexity, contributed to bank instability, and allowed water to travel more quickly downstream.

Agriculture and forestry continue to be the predominant land uses in the Satsop River watershed (See Figure 3). Farms in the Satsop River valley primarily produce dairy products, beef cattle, and corn. Small commercial businesses continue to operate in the town of Satsop. Low density rural residences are also spread around

Figure 3. Zoning Map



the valleys. Many of the families in the Satsop watershed have lived there for multiple generations and have very strong connections to the landscape.

The Satsop Business Park is located approximately 1.5 miles southeast of the confluence of the Satsop and Chehalis Rivers. The business park is managed by the Port of Grays Harbor. The Satsop Business Park is an adaptive reuse of the never-completed Washington Public Power Supply System nuclear power plant facility. Keys Road, which parallels the Lower Satsop river, provides a primary transportation connection to the Business Park. Keys Road was re-aligned to improve truck access to the power plant. This brought the road closer to the Satsop River and reduced the channel migration corridor. A well originally created for the nuclear power plant off Keys Road still serves the Business Park. A rock revetment that protects the well is experiencing erosion. The Port is in the process of constructing an alternative potable water system to serve the Business Park. The alternative water system will serve as a backup in the short-term and become the primary water system when the revetment eventually fails and the well along Keys Road is decommissioned.

[4]Salmon and steelhead habitat limiting factors: Chehalis Basin and nearby drainages Water Resource Inventory Areas 22 and 23. Smith, C.J. and M. Wenger. Prepared for Washington State Conservation Commission, May 2001

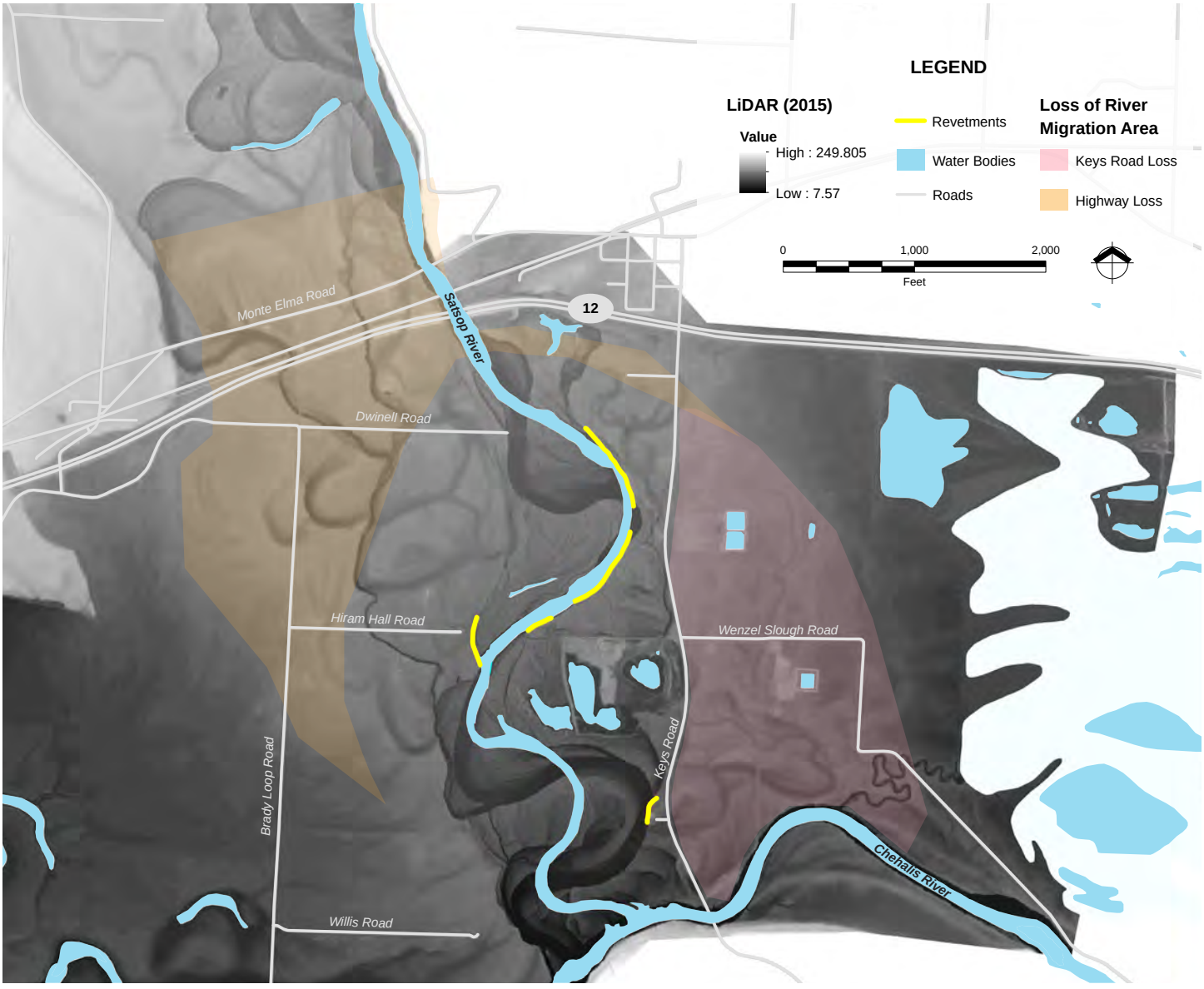
River Dynamics

The Satsop is a powerful river, draining a large watershed with a steep drop from its headwaters in the Olympic Mountains to the flat floodplain in its lower valley. The river has a history of migrating widely and at times suddenly across its floodplain.[5] This is a typical dynamic in rivers that flow down from steep terrain, carrying high loads of sediment that are deposited when the river reaches flat valleys. The sediments are deposited in a wide area called an alluvial fan. The unconsolidated gravels and sediments are easily eroded by the strong force of the river flow.

Before significant human development, the Lower Satsop River was free to migrate across its alluvial fan. Topographic maps show the scars of historic locations of the Lower Satsop River channel across an approximately 3,000-foot wide area. Notably, most of the channel scars are east of the current river channel. Higher elevation ground on the west side of the river do not have these scars, but currently the west bank is experiencing a high degree of erosion near the mouth of the river (See Figure 4).

[5]Watershed Science and Engineering. Lower Satsop Floodplain Restoration Phase II Final Report. Prepared for Washington Department of Fish and Wildlife. February 16, 2017.

Figure 4. LiDAR Map with Revetments



Data Source: Watershed Science and Engineering

Over time, infrastructure built along the river bank and in the floodplain limited its ability to move across the alluvial fan, including:

- The railroad and highway bridges that confined the main channel into a set location at their crossings.
- Keys Road, which was realigned in the late 1970s to provide better access to what is now the Satsop Business Park, limited the river's ability to migrate east.
- Revetments in multiple locations on the river bank limit erosion in specific locations but likely increase erosive force on the opposite bank.

To address erosion of the western bank at the mouth of the Satsop River, a relic channel was reconnected in 2004. By reconnecting a historic channel, the mouth of the river was shifted eastward, but, by 2013, the channel had moved back to very near its 2003 location.[6] Since revetments limit channel migration to the east, and there is no similar limit to migration to the west, the channel has continued to migrate westward into the high ground, eroding agricultural land at a rate of up to 80 feet per year.

The steep terrain of the Satsop River watershed leads to the river having a relatively quick response to heavy rain events.[7,8] The Satsop River typically rises one or two days before the Chehalis River during flood events. When the Chehalis River is in flood stage, it creates a hydraulic barrier that limits the ability of the Satsop River to recede. The highest observed discharges in the period of record occurred in March 1997 (63,200 cubic feet per second [cfs]), December 1999 (54,500 cfs) and December 1994 (50,600 cfs). Recent high flows include the January 2009 event (45,500 cubic feet per second (cfs)) and the November 2012 event (28,900 cfs).

Fish and Wildlife Habitat

The Satsop River Basin is an important component of salmon and steelhead habitat in the Chehalis Basin. The Satsop basin contributes approximately 33% of fall-run Chinook, 33% of winter-run steelhead, and 18% of the coho population of the entire Chehalis River Basin upstream of the Wishkah River.[9]

The Satsop Basin is important habitat for salmon and steelhead and has high enhancement potential. The watershed is predominantly in forest or agricultural land use with less than 10% development. However, studies have indicated that habitat quality in the river and adjacent riparian areas is in relatively poor condition. Contributing factors include:

- Lack of riparian forest and characterization of existing riparian forest as dominated by deciduous, rather than coniferous trees.
- Erosion and high inputs of fine sediments from logging roads and landslides.
- Lack of large woody debris in the channel.
- Water quality impairment, including elevated temperature and elevated siltation.

[6]Watershed Science and Engineering. Lower Satsop Floodplain Restoration Phase II Final Report. Prepared for Washington Department of Fish and Wildlife. February 16, 2017

[7]Watershed Science and Engineering. Lower Satsop Floodplain Restoration Phase II Final Report. Prepared for Washington Department of Fish and Wildlife. February 16, 2017

[8]West Consultants. Satsop River Floodplain Restoration Project. Prepared for US Army Corps of Engineers. May 5, 2004.

[9]Aquatic Species Enhancement Plan. Chehalis Bain Work Group. August 29, 2014.

An example of the major avulsion events that commonly occur on the Satsop River putting homes and infrastructure at risk.

Drivers of Flooding and Erosion

In at least the last 100 years, the Satsop River basin has experienced frequent flooding and wide migration of the river channel. The topography of the basin indicates that the river moved across its floodplain over the past several hundred or thousands of years. While flooding and channel migration appear to be intrinsic characteristics of the Satsop River, it is likely that changes to the watershed have increased the frequency of these events. Based on the previous studies of the Satsop River Basin, the key drivers to flooding and erosion appear to be:

- Steep grades and gravel-rich geology in the upper watershed leads to erosion and large amounts of sediment moving downstream.
- Broad flat topography of the lower watershed leads to slower river flows that allow sediments to drop out, creating a floodplain that is highly susceptible to erosion.
- Land clearing for agriculture and forestry, along with removal of large woody debris from the river, has reduced the natural structures that historically stabilized banks.

GRAVEL HARVESTING

Local community members have stated that historic gravel harvesting reduced bank erosion and channel migration. Because of its abundant gravel supply, the Satsop River and its floodplain were also historically used as a source of gravel. Local landowners used selective gravel removal as a means of protecting their land from erosion, as well as providing a valuable building material. Since this sort of extraction was poorly documented, it is difficult to determine how much gravel was removed from the Satsop. It has been estimated that up to 20,000 cubic yards were extracted annually beginning in the mid 1960s.[10] Between 1978 and 1982, extraction rates ranged from 10,000 to 40,000 yards^3 (8,000 m^3 to 30,000 m^3) per year. As shown in Figure 5, the river also migrated widely across the floodplain during that same period. It is difficult to quantify the effects of gravel harvesting on channel migration, but the practice did not completely halt channel migration.

While historically the Satsop River appears to have moved laterally, development in the floodplain has placed valuable assets at risk to erosion and flooding.

[10]Collins, B.D., and T. Dunne, Gravel Transport, Gravel Harvesting, and Channel-Bed Degradation in Rivers Draining the Southern Olympic Mountains, Washington, USA. Environmental Geology and Water Sciences 3:213-224, 1989

November 2018 Avulsion

Another avulsion of the Lower Satsop River occurred on November 27, 2018 during a heavy rain event. The river cut through a historic channel on the west bank, shortcutting a large meander bend.

This avulsion has put private homes at great risk of complete loss due to erosion. In addition to the actions described in this plan, emergency protection measures are being developed to address this urgent concern.

This most recent avulsion further emphasizes the need for urgent action to implement projects including those in this plan to stabilize the river system.

Map Credit: KPFF.

Figure 5. River Migration Map

THE PLANNING PROCESS

CHAPTER OVERVIEW

The community has been engaged in discussions about the Satsop River for a long time. The purpose of this project was to work with the community and regulatory agencies to identify feasible solutions, establish priorities, and develop an investment plan that will help the community start implementing projects that have agency support and a clear path forward.

For more than a decade, studies of the Satsop River have been conducted and plans developed to try to reduce erosion and flood risk. Individual property owners have taken actions to try to protect their land. No silver bullet solution has been identified. There are multiple drivers of flooding and erosion and multiple areas that are impacted. Projects that prevent erosion in one place may make it worse in another. Projects that may reduce flooding may also impact existing infrastructure or habitat. The different perspectives of various stakeholders have often come into conflict.

Despite these challenges, progress is being made. Funding has been provided by Washington State through the Chehalis River Basin Flood Authority and other programs to support planning and implementation of projects to reduce erosion and flood risk as well as enhancing natural habitat. Grays Harbor County convened different interest groups together to coordinate efforts and develop a long-term plan for the Lower Satsop River. The County was supported in this effort by the GHCD to increase engagement of local property owners.

Identifying solutions on the Satsop River has proven difficult over the past several years with conflicts arising between the surrounding landowners' need for swift and effective action and the regulatory agencies that no longer allow some of the methods of river management that existed in the past. To address this conflict, the Satsop Investment Plan process held parallel engagement processes with an Advisory Group composed of representatives from the County, GHCD, and federal, state, and local public agencies as well as meetings with the community. Through a series of Advisory Group and community meetings, participants engaged in a planning process involving the following steps.

All materials from the community and Advisory Group meetings are available in Appendices A and B, respectively.

Defining the Challenge
Property Owner Meetings
Advisory Group Meeting #1

Identifying Solutions
Community Meeting #1
Advisory Group Meeting #2

Evaluating Options
Advisory Group Meeting #3

Prioritizing Projects
Community Meeting #2
Advisory Group Meeting #4

Planning for Action
Community Meeting #3
Advisory Group Meeting #5

Defining the Challenge

The first step of the planning process was to understand the characteristics of the Satsop River and the problems the community was facing. The project team reviewed and synthesized the findings of previous technical studies of the Satsop River. The project team also met with property owners along the Satsop River to see first hand the issues the community was facing. Throughout the project the GHCD continued to reach out to landowners along the Satsop River. The technical information from previous studies and the local experiences of community members were shared during the first Advisory Group meeting and the first Community Meeting.

ISSUES EXPERIENCED BY PROPERTY OWNERS TODAY

The primary concerns of property owner expressed in personal interviews and the community meetings were:

Bank Erosion: The Satsop River channel has been migrating, causing significant bank erosion. In some places the river has moved 40-80 feet in a year and taken out mature stands of trees. Community members emphasized that bank erosion and loss of property are their biggest concerns.

Sediment Deposition: Community members have watched gravel bars grow and shift in the middle and lower reaches of the river. Anecdotally, people have said that pools are filling with gravel and the river is becoming shallower. Gravel is deposited in large bars in the inside of river bends. Erosion occurs on the outside of the bends.

Combined Flooding from the Satsop and Chehalis River: Long-time residents said that they are used to the Satsop River flooding. There is some perception that river levels are rising faster, and floods are coming at lower river stages. Land along the Lower Satsop River is also in the floodplain of the Chehalis River. When high flows on the Chehalis River coincide with flood events on the Satsop River, the drainage of the Satsop River is limited, and water elevations rise and remain in flood stage for extended periods.

Reduction of Forest Cover: The history of extensive logging in the watershed may be contributing to flooding and channel migration. It was discussed that current forest practices laws are more protective than in the past, but that impacts from past practices are still affecting the dynamics of the river.

PARTICIPANTS ON THE ADVISORY GROUP

- Grays Harbor Conservation District
- Grays Harbor County
- Port of Grays Harbor
- Washington State Department of Fish and Wildlife
- Washington State Department of Natural Resources
- Washington State Department of Ecology
- Washington State Department of Transportation
- U.S. Army Corps of Engineers

Project team members meet with Terry Willis (left) and Tracy Baker (right), both of whom are multi-generational farmers living and working along the Satsop River.

Identifying Solutions

With a shared understanding of challenges, goals, and the work conducted in previous studies, the planning process moved to identifying potential solutions. An open community meeting and an Advisory Group meeting were held in September 2018 to focus on identifying potential solutions. During these meetings, the project team presented the wide range of potential solutions that had been discussed in previous reports, suggested by landowners, and/or implemented on other similar river systems. At each of these meetings, attendees used maps of the watershed to suggest places where different solutions could be implemented. From these meetings, the project team created a list of potential solutions. The potential solutions are described in Figure 6.

It is important to note that throughout the discussion of potential solutions, a general consensus emerged that solutions that could be realistically funded and implemented would need to work with natural processes and provide multiple benefits to property, infrastructure, and habitat. Participants in the planning process demonstrated that they valued the local economy, community, and fish and wildlife. They were open to exploring innovative solutions to meet all of the planning goals.

Evaluating Options

In October 2018, the Advisory Group convened to review the potential solutions and evaluate their feasibility and benefit. Each participant's response was aggregated into an average benefit and feasibility score (see Table 1).

Benefits Elements

Flood reduction: The extent to which the solution will help prevent flooding.

Habitat: The extent to which the solution will enhance habitat in or along the river for fish and wildlife.

Erosion: The extent to which the solution would contribute to erosion prevention.

Recreational: The extent to which the solution has recreational value to people who like to recreate on the Satsop River.

Infrastructure: The extent to which the solution protects important local infrastructure.

Feasibility Elements

Effectiveness: How quickly and effectively the solution would realize its benefits.

Cost/Funding: How expensive the solution is in terms of design, construction, and maintenance.

Permitting: How easy or difficult it would be to get the solution permitted through all the necessary regulatory agencies.

Longevity: How long the solution would be able to remain in place and create benefits for the community.

Table 1. Benefits and Feasibility Assessment of Projects

PROJECT	BENEFITS TOTAL	FEASIBILITY TOTAL	TOTAL
Engineered Log Jams	11.71	10.04	21.75
Small-Scale Large Woody Debris Projects	11.29	10.30	21.59
Flood Easements and Conservation Easements	11.00	10.23	21.23
Keys Road – Relocation	11.79	9.00	20.79
Floodplain Property Acquisition from Willing Sellers	10.00	10.02	20.02
Keys Road – Elevated Causeway	11.00	8.86	19.86
Side Channel Habitats	10.71	9.11	19.82
Conservation Practices on Forestry Lands	10.00	9.55	19.55
Restoration of Gravel Ponds on WDFW Property	9.43	8.95	18.38
Keys Road – Armoring	9.29	8.21	17.50
Keys Road – Permeating with Culverts	8.43	8.54	16.96
Pilot Channel	8.29	6.77	15.05

Figure 6. Project Descriptions Provided to Assist in Prioritization

CONSERVATION PRACTICES ON WORKING FOREST LANDS

Collaborate with working forest managers to ensure that best practices are being met. Additionally, explore opportunities to increase riparian buffer widths, selectively harvest, or increase harvest rotation intervals. Implementation of conservation practices in the headwaters of the Satsop River has the potential to decrease runoff, erosion, and sediment transport in the system.

Flood	Habitat	Erosion
2.2	2.3	2.2

ENGINEERED LOG JAMS

Place engineered complexes of large wood pieces in strategic locations in stream channels. Engineered log jams would be used to slow bank erosion, promote formation of side channels, increase channel roughness to slow velocity and encourage high flows to spread into the floodplain. Large wood plays a key role in stream morphology. They can promote formation of pools, gravel bars, and side channels. They can stabilize river banks and increase floodplain connectivity.

Flood	Habitat	Erosion
2.0	2.9	2.7

FLOOD EASEMENTS AND CONSERVATION EASEMENTS

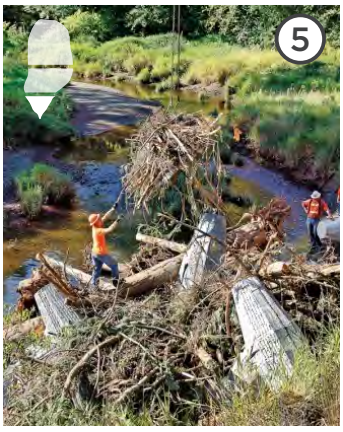
Collaborate with willing private property owners to obtain easements for flood storage and habitat conservation on private property. Under a flood easement, the owner would be restricted from building structures in the dedicated area and would manage that land proactively. Provides land area for flood storage and channel migration without impacting infrastructure and structures. Increased roughness and diversity of structure in the floodplain also serves to slow flood velocities.

Flood	Habitat	Erosion
2.6	2.4	2.3

KEYS ROAD - HARD ARMORING

The current alignment of Keys Road would be maintained and protected using traditional techniques such as sheet pile wall. Protect Keys Road as a transportation corridor that connects Satsop Business Park and residences to State Route 12. Maintaining the existing alignment also provides erosion protection to farmland east of the road.

Flood	Habitat	Erosion
1.4	1.0	2.7



KEYS ROAD - SOFT ARMORING

The current alignment of Keys Road would be maintained and protected using bio-engineering techniques such as rip rap and large woody debris. Protect Keys Road as a transportation corridor that connects Satsop Business Park and residences to State Route 12. Maintaining the existing alignment also provides erosion protection to farmland east of the road.

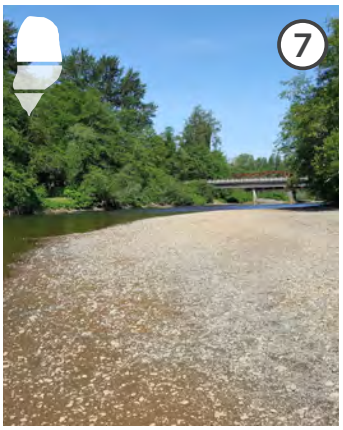
Flood	Habitat	Erosion
1.4	2.0	2.7

KEYS ROAD - RELOCATION

Keys Road and the natural gas line that runs in its right-of-way would be relocated to the east, closer to its historical alignment. This option would allow the Satsop River to migrate more freely to the east within its historical alluvial fan. Allowing the river to migrate to the east should reduce bank erosion on the west side. This option would allow flood water to spread more broadly across the floodplain.

Flood	Habitat	Erosion
2.5	2.3	2.4

Figure 6. Project Descriptions Provided to Assist in Prioritization (cont.)



IN-STREAM GRAVEL MANAGEMENT STUDY

In coordination with an engineered log jam project or bank stabilization project, relocate gravel within the limits of the top of bank of the river. The movement of gravel could promote adjustments of the channel that the engineered log jam or bank stabilization project is designed to achieve.

Flood	Habitat	Erosion
1.9	1.8	2.6

PILOT CHANNEL

A pilot channel is created by excavating in a low lying area, anticipating the eventual direction of the river, and creating an avulsion that redirects river flows into the pilot channel and away from eroding banks. Pilot channels can reduce the meandering of the river which can result in reduced bank erosion and loss of property within the floodplain. Pilot channels also have the potential to increase storage in the floodplain as the old channel becomes a backwater or oxbow habitat area.

Flood	Habitat	Erosion
1.4	1.7	2.1

PROPERTY ACQUISITION FROM WILLING SELLERS

Purchase land from willing private property owners. These properties would then be managed to allow for periodic flooding and channel migration. The lands could be proactively planted with native trees and shrubs to stabilize river bank, increase floodplain roughness, and increase habitat structure and diversity.

Flood	Habitat	Erosion
2.1	2.0	2.3

RECONNECTING HISTORIC SIDE CHANNELS

Encourage the river to flow more broadly across its floodplain in strategic locations to slow velocities, increase storage in the floodplain, and increase habitat diversity. Side channels distribute and attenuate high river flows by encouraging the river flow to split between the main channel and side channels, the velocity of the water can be slowed and the volume of water that can stored during flood events can be increased.

Flood	Habitat	Erosion
2.3	2.4	2.3

RESTORATION OF GRAVEL PONDS ON WDFW PROPERTY

Floodplain restoration through removal of approximately 164,000 cubic yards of spoils from the floodplain and using some of the material to partially fill former gravel pits to create shallow water habitat. Hydraulic and hydrologic modeling of the project indicate that it will have a small reduction in flood elevation and erosion risk, but the effect is primarily limited to the WDFW property itself.

Flood	Habitat	Erosion
1.7	2.4	1.6

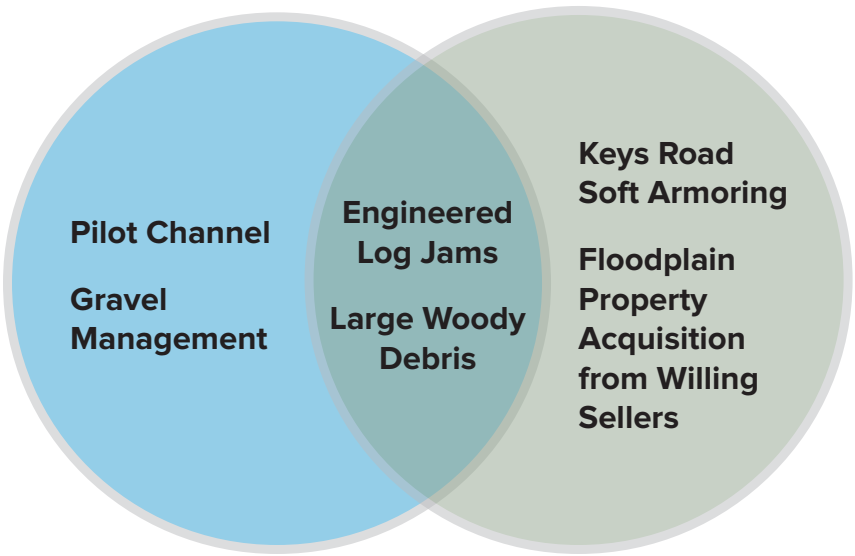
SMALL-SCALE LARGE WOODY DEBRIS PROJECTS

Place large wood in discrete locations in stream channels. The large would could range from single pieces to multiple pieces configured as a log jam. The large wood could be anchored or not depending on location, design, and risks. Large wood can provide protection against stream bank erosion. The ability of large wood to trap sediment, decrease flow velocity, and spread flood flows in a reach can reduce erosion and flood risk in downstream reaches.

Flood	Habitat	Erosion
2.0	3.0	2.6

Prioritizing Projects

With the information in hand from the previous steps, the planning process then focused on finding alignment among diverse stakeholders by prioritizing projects. In November 2018, the second community meeting and fourth Advisory Group meeting were held so that these groups could prioritize the potential projects. To do this, the project team walked both groups through a prioritization exercise that gave participants a "budget" and a cost sheet for the projects discussed during Identifying Solutions. This exercise helped the project team understand which projects were the most important to the community. In order to gain as much input from the community as possible, the meeting materials and prioritization exercise were incorporated in an online survey that was held open from November 14, 2018 to November 30, 2018 and received seven responses. The Venn diagram below shows where project priorities overlapped between the community and the Advisory Group. The project descriptions provided to the community and Advisory Group are shown in Figure 6.



The community (left) and Advisory Group (right) meet on November 13, 2018 to prioritize the proposed projects for the Satsop River.

Planning for Action

With the priorities identified, the planning process next moved to developing an implementation strategy that included phasing and funding. The project team held the final meetings for this effort in January 2019 with both the Advisory Group and the community. The purpose of these meetings was to discuss the draft investment plan and examine the next steps towards implementation of projects.

PLACEHOLDER FOR JANUARY 2019 MEETING SUMMARY

INVESTMENT PLAN

CHAPTER OVERVIEW

The Investment Plan is the result of the collaboration of many stakeholders throughout the planning process. It includes the priority projects, the lead agency responsible for carrying them forward, a timeline for implementation, and a funding plan. There are also programmatic recommendations to establish a standing advisory committee to guide implementation, regular meetings with local landowners to continue their engagement, and creation of a monitoring plan to evaluate the effectiveness of the projects.

A set of recommended programs and projects has been developed based on review of technical studies and input from public agencies and local community members. Because erosion, flooding, and habitat degradation occur throughout the watershed and are driven by a combination of multiple factors, there is no single, silver bullet solution. This plan proposes a set of interrelated programs and projects that can be implemented in multiple locations across the watershed in phases that, collectively, will contribute to reducing erosion and flood risk while also enhancing fish and wildlife habitat and providing other benefits. While some projects are large-scale public works, a number of small-scale, lower cost actions are also recommended. The recommended actions are based on a review of research studies and leading-edge planning in the Pacific Northwest region and across the country. These examples have been combined with local experience and tailored to the challenges and opportunities of the Satsop River Basin.

The Investment Plan is based on an approach that works with natural river processes while respecting the importance of protecting agricultural land and infrastructure that supports the community and the local economy. The approach recognizes that the river will continue to migrate and that some land needs to be set aside to let that natural process occur, while in key places that movement needs to be limited. Bio-engineering with natural materials will be used to the extent practicable so that bank protection projects will also provide habitat value. Projects will be designed to achieve multiple benefits for reducing erosion and flood risk, enhancing habitat, and protecting farm and forestry land.

In natural conditions, rivers regularly overtop their banks, and water flows through the adjacent floodplain. Ecological systems have adapted to this regular flooding in a number of ways. Floodplains are generally flat areas with trees, vegetation, and physical structures that slow and store flood waters. By slowing and storing floodwaters, naturally functioning floodplains can reduce flooding in downstream areas. Large, mature conifer trees and log jams are critical to stabilizing river banks. The Investment Plan approach seeks to re-establish historic riparian and river conditions, when feasible, to stabilize banks and reduce erosion. However, in locations where critical infrastructure and highly valued community and economic assets are at risk, targeted bank protection measures may need to be implemented.

Programmatic

To provide guidance for implementing and updating this Investment Plan, it is recommended that a standing advisory committee be established. The advisory committee should include local property and business owners along with representatives of the public agencies that participated in creation of this plan. Additionally, the community requested that the County hold semi-annual meetings in the spring and fall to update them on the status of the Investment Plan projects.

A monitoring plan should also be established to track implementation and evaluate factors related to flooding, erosion, habitat, and channel morphology in the Satsop Basin. The monitoring plan should be designed to provide accurate and applicable data and should be limited enough in scope and complexity to increase the likelihood of long-term continuation.

Projects

The priority projects can be categorized into five basic types. The appropriate location of these project types depends on location in the watershed and site-specific factors.

Land Conservation. Promoting establishment of mature riparian forests is fundamentally important to reducing erosion in the Satsop Watershed. Land in the floodplain should also be managed to anticipate future channel migration and allow the river room to move when feasible. Land conservation can be achieved through a number of methods. As part of the Chehalis Basin Aquatic Species Restoration Program, a conservation toolbox is being developed to provide property owners and land managers with resources on different approaches and programs. All of these options assume working with willing property owners. Options include:

- ***Flood Easements and Conservation Easements.*** Property under an easement continues to be in the same ownership, but certain uses are allowed or restricted. Under a flood easement, the owner would be restricted from building structures in the dedicated area and would manage that land proactively, planning for periodic inundation.

  Conservation easements also restrict development and may include provisions for managing the land as natural habitat. There are various approaches for completing easements including tax benefits or direct monetary compensation. These areas could be proactively planted with native trees and shrubs to stabilize river bank, increase floodplain roughness, and increase habitat structure and diversity.

- ***Conservation Practices on Working Forest Lands.*** The Forest Practices Act and the Forests and Fish Law establish high standards for managed timberlands. They also provide incentives for increased riparian buffer widths and selective harvest techniques that could be more actively pursued. Tools such as conservation easements and carbon credits could also be used to promote conservation practices beyond regulatory requirements.

Small-Scale Large Woody Debris Projects. Large wood plays a key role in stream morphology. Historic logging and land management practices removed large woody debris from the Satsop River and rivers across the northwest. Projects adding large wood back into streams attempt to restore the channel forming processes that historically occurred. In small, headwater channels, the large wood is expected to trap sediment, stabilize banks, and increase habitat complexity. In lower gradient channels, large wood can stabilize banks, promote formation of side channels, increase channel roughness, and promote high flows to spread into the floodplain decreasing velocity and flood elevation downstream.

- ***Upper Satsop River.*** Develop a strategy and implement multiple large woody debris projects in the upper watershed to slow flow, improve floodplain connectivity, and reduce bank erosion.

Engineered Log Jams. Engineered log jams are larger structures than the large woody debris types of projects. Typically, engineered log jams include 10 or more pieces of large wood, ballast rock, and sophisticated design to stabilize the structure. Engineered log jams could be used to slow bank erosion, promote formation of side channels, increase channel roughness to slow velocity, and encourage high flows to spread into the floodplain. Engineered log jams can influence channel morphology. They can promote formation of pools, gravel bars, and side channels. They can stabilize river banks and increase floodplain connectivity. The potential erosion and flood impacts of engineered log jam structures need to be carefully analyzed to evaluate risks to upstream and downstream properties and infrastructure.

- ***Lower Satsop River.*** A series of engineered log jams is proposed downstream of the SR-12 bridge to diffuse flow velocity and reduce bank erosion.
- ***East Fork Satsop River.*** A series of engineered log jams and bio-engineered bank protection measures are proposed on River Mile 7.8 to 10.8 to reduce bank erosion and enhance habitat.

Bank Armoring. In locations with critical infrastructure, it may be necessary to employ bank armoring techniques to prevent erosion. New techniques that combine large wood, rock, and engineered concrete structures can be applied to provide bank protection in a manner that isn't as impactful to natural habitat as traditional rip-rap, sheet pile, or levees. These techniques may be needed to protect sections of Keys Road, bridge abutments, and homes on the Satsop River.

Keys Road. Keys Road is an important transportation corridor that connects Satsop Business Park and residences to State Route 12. The road is located within the alluvial fan of the Satsop River in an area with topographic markers of historic channel scars. As the river migrates to the east, portions of Keys Road are at risk of erosion. From a natural river process perspective, the ideal solution for Keys Road would be to relocate it further away from the Satsop River. However, there is limited physical ability to relocate Keys Road away from the Satsop without also constructing a new bridge across the Chehalis River. The combination of a new bridge and new road would likely cost over $10 million.

This Investment Plan proposes a phased approach to Keys Road, Bank protection should be installed with an expected lifespan of 30-40 years, which is approximately the remaining useful life of the existing bridge over the Chehalis River. In the long-term, a new bridge and new road location can be planned, designed, and constructed to move the transportation corridor into a lower hazard area. With a shorter design life, bio-engineering techniques using large wood and rock could be installed that would have less habitat impact than traditional bank armoring.

HOW THIS PLAN ADDRESSES GRAVEL MANAGEMENT

The geology and topography of the Satsop River watershed make it a gravel-rich system. Historically, gravel was harvested from the river by commercial operations and private landowners. Current environmental regulations no longer allow this practice. WDFW research on gravel harvesting indicates that effects of the practice on flooding and erosion are mixed. Historic evidence in the Satsop River illustrates that during the period when gravel was actively harvested from the river, lateral migration continued to occur. A number of local community members strongly believe that gravel management is needed to control river migration.

There is an opportunity to test and monitor the effects of gravel management at a pilot scale through integrating movement of gravel within the river banks into the design and construction of projects such as ELJs. This approach can work within the requirements of environmental regulations and address the concerns of local community members as much as possible.

Investment Plan

The Investment Plan below demonstrates how projects will progress in the next three biennia. This includes the agency(ies) that have agreed to act as lead advocate for each project. Table 2 below describes how each project will be funded.

Table 2. Investment Plan

PROJECT (LEAD AGENCY)	NEAR-TERM 2019-2020	MEDIUM-TERM 2021-2025	LONG-TERM 2026-2045	FUNDING SOURCE
Large Woody Debris in Upper Watershed (GHCD) *Slow river velocity to reduce erosion and enhance habitat*	Design & Construct Pilot *$350K*	Design & Construct (3-5 mi) *$425K - 725K*	Design & Construct (15-20 mi) *$2 M - $3 M*	WQ Grants, WCRI, CRBFA
Engineered Log Jams on East Fork of Satsop River (GHCD) *Bank stabilization and habitat enhancement*	Design & Construct *$6.8 M*			Chehalis Basin Strategy
Keys Road Soft Armoring (GHC) *Protection of key public infrastructure while minimizing environmental impact*	Design *$375K*	Construction *$2 M - $2.5 M*	Maintain & Monitor *$50K*	CRBFA, GHC
Infrastructure and Long-Term Asset Planning (GHC) *Evaluate options for changes in coordination with eventual bridge replacement*			Plan for and Implement Modifications *$TBD*	GHC
Engineered Log Jams on Lower Satsop River (GHCD) *Bank stabilization and habitat enhancement*	Design *$50K - $75K*	Construct *$150K - $250K*		WCRI, WWRP, CRBFA, FbD
Gravel Ponds, Phase 1 (WDFW) *Increase floodplain connectivity and enhance habitat*	Construct *$1 M*			WCRI
Gravel Ponds, Phase 2 (WDFW) *Increase floodplain connectivity and enhance habitat*		Construct *$1.7 M*		WCRI
Engineered Log Jams - Other Locations (GHCD) *Address bank erosion to protect farm land and infrastructure, including bridges*		Feasibility Study *$150K*		CRBFA, FbD, WCRI, WWRP, SRFB
Land Conservation (Multiple Agencies) *Increase flood plain connectivity and enhance habitat*		As Opportunities Arise with Willing Sellers		CRBFA, FbD, WCRI, WWRP, SRFB

TABLE KEY

Location in the Watershed

- *Upper watershed*
- *Middle watershed*
- *Lower watershed*
- *Across entire watershed*

Acronyms

CRBFA: Chehalis River Basin Flood Authority
FbD: Floodplains by Design
GHC: Grays Harbor County
GHCD: Grays Harbor Conservation District
SRFB: Salmon Recovery Funding Board
WCRI: Washington Coast Restoration Initiative
WDFW: Washington State Department of Fish & Wildlife
WQ Grants: Coordinated Water Quality Grants
WWRP: Washington Wildlife and Recreation Program

Future Funding Strategy

Significant funding will be needed to implement these projects. By taking an approach that incorporates habitat enhancement, flood and erosion risk reduction, and public infrastructure improvements, there are significant benefits generated that outweigh the costs. There are multiple potential sources of federal and state funds to support these projects. Table 2 provides preliminary planning level forecasts and likely funding sources for each project.

While a lot of funding is required to design, construct, maintain, and monitor these projects, there are ample funding sources available. The list below summarizes the funding sources that would be best suited to support both the programmatic efforts and projects.

Federal Funding

- Federal Emergency Management Agency (FEMA)
  - Pre-Disaster Mitigation Grant Program
  - Flood Mitigation Assistance Program
- U.S. Department of Agriculture
  - Business and Industry Guaranteed Loan Program

State Funding

- Washington State Department of Ecology (Ecology)
  - Floodplains by Design
- Washington State Recreation and Conservation Office
  - Aquatic Lands Enhancement Account
  - Washington Wildlife Recreation Program
  - Chehalis River Basin Flood Authority
  - Salmon Recovery Funding Board
  - Washington Coast Restoration Initiative
- Washington State Department of Natural Resources
  - Urban and Community Forestry Program
- Transportation Improvement Board (TIB) Programs
  - Urban Arterial Program
  - Arterial Preservation Program

Return on Investment

The investments in this plan are essential for the long-term sustainability of the community and economy of the Satsop River Valley. Farms in Grays Harbor County produce over $30 million in marketable products every year. Investments in erosion and flood risk reduction protect the agricultural heritage of the Satsop River. These investments also protect critical transportation infrastructure. SR 12 is the primary transportation corridor connecting the Washington coast. Keys Road is the main entrance to the Satsop Business Park that supports over 400 jobs. The proposed projects also enhance habitat for salmon in one of the most productive tributaries to the Chehalis River.