



RESTORATIVE FLOOD RESPONSE COMMUNITY HANDBOOK



Cover Photo Credits:
Upper right corner: USFS

creative commons (<http://creativecommons.org/about>)
copyright 2015 | free for non-commercial reproduction

Restorative Flood Response Community Handbook

Sandy River Basin Watershed Council

Working together to restore the Sandy River

26000 SE Stark Street, GE Building
Gresham, OR 97030
503.622.9134
www.sandyriver.org

Steve Wise, M.S.
Executive Director
swise@sandyriver.org

Corinne Handelman, M.S.
Community Stewardship Coordinator
corinne@sandyriver.org

Sponsored by:

patagonia[®]

Natural Systems Design

1900 N. Northlake Way, Suite 211
Seattle, WA 98103
206.834.0175
www.naturaldes.com

Tim Abbe, Ph.D, P.E.G, P.H.G
Principal Geomorphologist
tim@naturaldes.com

Mary Ann Reinhart, M.S., P.E.G.
Senior Geomorphologist
maryann@naturaldes.com

Shawn Higgins, M.S.
Project Geomorphologist
shawn@naturaldes.com

David French, B.S.
Fluvial Geomorphologist
david@naturaldes.com





TABLE OF CONTENTS

- Glossary** 1
- Acknowledgments** 2
- Introduction** 3
- The Dynamic Sandy** 4
- Salmonid Habitat Requirements** 11
- Assessing Risk** 18
- Toward Restorative Solutions** 20
- Getting Started in Your Neighborhood** 27
- Additional Restorative Flood Response Resources** 28

Glossary

Avulsion	A form of migration where the river abandons its current channel to occupy a newly formed, or older abandoned channel.
Atmospheric River	A meteorological term describing relatively bands of moisture laden air that are typically a few thousand miles long but only a couple miles or less in width. They carry water vapor evaporated from equatorial regions to the mainland where they are responsible for the most severe flood events.
CMZ	Channel migration zone – the area a river is likely to move into with time, representing an erosion hazard area.
Gradient	The slope or steepness of the river, measured as the vertical drop over a particular distance.
EPAL	Erosion Protection Action Line – Boundary at which bank structures may be necessary to reduce erosion risk for critical infrastructure, assuming sufficient space is provided to allow channel migration to occur.
ELJ	Engineered Logjam
Flood Frequency	The likelihood a given flow level will occur in a given year. A 100-year flood has a 1 percent likelihood to occur in a given year.
Lahar	Volcanic mudflows initiated near the volcano that rapidly move down river valleys and can bury large portions of a river valley. Typically occur during times of volcanic activity such as steam releases that can melt glaciers and introduce large quantities of water to unconsolidated sediments. Because of their high density, mudflows can easily move boulders as large as cars and small houses.
Pineapple Express	Regional term on the west coast of North American for Atmospheric River events that carry moisture from the central Pacific Ocean to California, Oregon and Washington where they result in prolonged periods of intense rainfall and flooding.
Revetment	Distinguishing between wood-based revetments, that can deflect energy and erosion, and traditional rip rap, which can accelerate and cause erosion.
Sediment	Rock fragments (silt, sand, gravel, cobbles and boulders).



Acknowledgments

This guide is the product of several years of community dialog, research, and collaboration among residents, experts and agencies. The Sandy River Basin Watershed Council wishes to thank our co-author, Natural Systems Design, for their significant contribution to much of the science presented in this document. We are also extremely grateful to Portland General Electric's Habitat Fund, the Timberline Rim Homeowners Association, and Patagonia's World Trout Initiative, who helped to fund the development of this guide. We also deeply appreciate the support and contributions of Clackamas County's Emergency Management staff, science and engineering personnel from Cardno Entrix, Inter-fluve, USDA Forest Service, and upper Sandy River residents including our neighbors in Timberline Rim, Autumn Lane, Zigzag Village, Salmon River Park, and other areas affected by the Sandy River's erosion, channel migration and flooding.

About the Sandy River Basin Watershed Council

The Sandy River Basin Watershed Council (SRBWC) is a leader in collaborative habitat restoration throughout the Sandy River and its tributaries including the Bull Run, Zigzag and Salmon rivers. Collecting flows from 500 square miles between the upper watershed and

Troutdale, the Sandy provides a haven for wild salmon and a full range of wildlife biodiversity.

The river also serves as the primary water supply and a year-round recreational retreat for the Portland region. The SRBWC leads the effort for achieving on-the-ground, science based restoration, stewardship, community engagement and education, with a mission to protect and restore the natural, cultural and historic resources of the Sandy Basin.

Watershed residents and land management agencies organized the SRBWC in 1997 to gather

community restoration efforts and provide input to Portland General Electric's decommissioning of Marmot Dam. Marmot's voluntary removal by PGE in 2007 -- the first and then largest in Oregon -- restored unimpeded fish passage to the headwaters of the 56-mile Sandy and its over 200 stream miles of tributaries. The Sandy basin which represents anchor habitat for threatened Lower Columbia River salmon and steelhead, is designated a key regional priority area for wild salmonid recovery, and is home to at least 21 other federal and Oregon state wildlife species of special concern.



Introduction

The Sandy River's January 2011 flood was one of many historic events that have changed the landscape along the river. Two days of heavy rain on deep snow at the river's headwaters on Mt. Hood created what turned out to be the third largest flood on record. The storm drove rushing waves of water, glacial debris and entire trees into a roiling torrent that blew out roads, threatened bridges, and destroyed houses. Within hours it carved away large stretches of river bank.

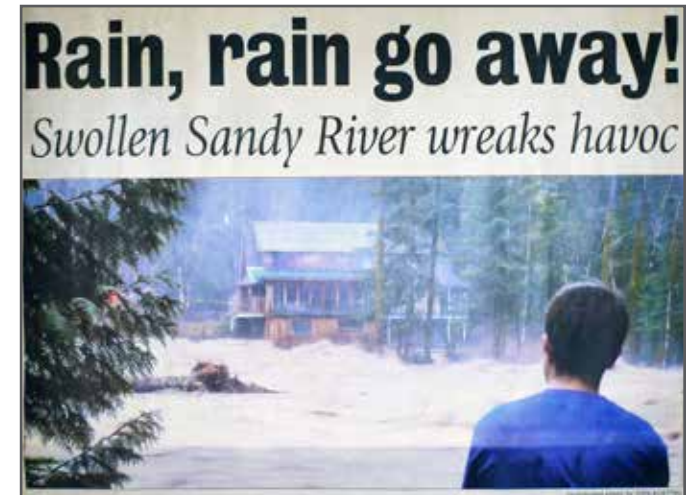
Besides the dramatic physical impacts, the 2011 flood caught peoples' attention in a new way. That year's event concerns about repeated, costly impacts from what seemed to be an increase in frequent, large floods in the upper Sandy.

Residents wanted to know what could be done to reduce risk in future events. The presence of threatened wild salmon meant that old approaches to stream bank stabilization were not acceptable since they adversely impact the habitat upon which salmon depend. Understanding natural river dynamics not only provides the foundation upon to restore, but also how to identify hazardous areas and reduce risks associated with flooding and erosion. Streamside vegetation and wider floodplains dissipate a river's energy and can improve critical salmon habitat while reducing the risks to homeowners and infrastructure. Straightening and clearing rivers, such as what happened to the Sandy in 1965, created many of the problems we are dealing with

today. Understanding how the Sandy responds to volcanic and climatic processes offers clarity in how to live and thrive with the river. To ignore the river's natural character is to invite problems. This handbook is intended to help the community find more sustainable solutions to reducing flood hazards and enhancing habitat in the Upper Sandy River.

Working together with several impacted neighborhoods, river experts, and public agencies, the Sandy River Basin Watershed Council set out on a path to describe a collaborative alternative we call Restorative Flood Response. Instead of trying to contain the Sandy's force, as historic post-flood actions would, Restorative Flood Response should build on the science of the river's natural processes including those driven by its volcanic and glacial environments, and overall channel behavior. This means that, instead of working on one property at a time, this approach seeks to work at the river reach scale, where a number of individual properties might be treated together. In addition, our evolving understanding of what makes for good habitat can be included in river and stream bank restoration designs that not only help recovery of wild salmon, and help to reduce flood related risks for homeowners and infrastructure.

This handbook is a starting point for community understanding and exploration of Restorative Flood Response. We hope that it answers questions regarding Sandy storms, and provides an understanding of channel migration. We look at what wild fish need, ways that habitat restoration can absorb and reduce the river's energy, and how people can begin to put these ideas into use. The practices described here won't apply to every situation, or necessarily eliminate risk from future storms, but we hope the concepts help focus the community's energy and investment toward sustainable actions that restore the Sandy's exceptional natural values while helping to address flood risk.



Residents have experienced increasingly frequent, intense storms. These have affected the Sandy, its banks, and surrounding infrastructure in recent years (Sandy Post photo).

The Dynamic Sandy

Clear water, majestic forests, and spectacular views make the Upper Sandy River valley a very attractive place to live... most of the time (Figure 1). But living alongside any river brings some degree of risk. The Sandy River, flowing from glaciers on the side of an 11,000 foot volcano, stands out as one of the more risky in the Pacific Northwest. While providing some of the best wild fish habitat in the Lower Columbia River Basin, the Sandy River is a particularly powerful system that is capable of tremendous impact to riverside structures (Figure 2). The Sandy can experience an exponential increase in its flow and force in a few hours. Given the definition of “dynamic” is something characterized by energy or effective action; vigorously active or forceful; energetic; pertaining to force or power; pertaining to force related to motion, it is adjective perfectly apt for the Sandy River.

The Sandy is at its most dynamic when it is at flood state. Clearly, that’s when the river is most energetic, most powerful, exerting the greatest forces along riverside properties and infrastructure. Salmon have been adapting to these fluctuations in flow for thousands of years, seeking shelter in off-channel areas along available floodplains to take refuge from the strongest currents. For residents, the process of adaptation is much newer: most of the residences in the upper Sandy have appeared since the 1970s, many along areas reclaimed after the record flood



Figure 1. The upper Sandy River is a place of majestic forests and spectacular views. However, this peaceful Zig Zag village home site was destroyed by the 2011’s flood and channel migration, and later acquired by Clackamas County.

in 1964. For today’s inhabitants, a dynamic Sandy River is one that causes major change along the river course, potentially threatening riverside properties, utilities, roads and bridges.

This handbook is intended as a primer to understand river functions, in particular those that make the Sandy unique. It will describe the Sandy’s recent

flood history and the processes driving bank erosion and channel migration, as well as the processes responsible for creating habitats in which salmon and other wildlife thrive. The handbook also provides the basics for how to assess risk of future impact, and how actions to anticipate future floods can improve conditions for the ecosystem and people.



Figure 2. While floods are infrequent, high winter flows and steep gradient give immense power to the Sandy River that can quickly erode soils and local property. View is along the western end of Lolo Pass Road during 2011 flood. Photo by Jay Wilson.

Recent Flood History

The Upper Sandy River has a long history of large storm events that have caused substantial flooding and bank erosion throughout the upper river corridor, upstream of the Salmon River confluence.

Major changes in the river usually occur during floods when storm flows are deepest. These flows begin small but often grow rapidly. As flood flow depths and velocities increase so do the effects of inundation and erosion. A critical factor that complicates erosion risks in the Upper Sandy is that many of the river's banks contain unconsolidated lahar soils, composed

of sand and rock from geologically recent volcanic events, that are more easily eroded than the river's own bed of cobbles and boulders (Figure 3).

Large magnitude storm flows occur at most a few days every year, but each event can result in dramatic bank erosion, with damaged roads and infrastructure. The magnitude of a storm's peak flow is typically defined as a probability. A peak flow with a one percent chance of occurring in any given year is commonly referred to as a 100-year flood.

The Upper Sandy River has a long history of large storm events that have caused substantial flooding and bank erosion throughout the upper river corridor, upstream of the Salmon River confluence. For example, in 1964 the Sandy experienced a flow of 61,400 cubic feet of water per second (CFS) at the site of the former Marmot dam. This flow had only a 0.4% probability of occurring in any given year, and so is referred to as a 250-year flood event. In 1996, the river peaked at 48,100 CFS, which translates to a flood recurrence of about 90 years. The 2011 flood

reached 39,000 CFS, which is equivalent to about a 40-year flood event. Over the last 100 years there have been 76 years with at least one peak flow exceeding 10,000 CFS.

The flooding of residences, roads and other infrastructure has caused millions of dollars of damage. In the last 50 years alone (1964-2014) bank erosion has claimed over 400 acres along the Upper Sandy, damaging or destroying roads, bridges, and homes.

The U.S. Army Corps of Engineers reported that 155 homes were completely destroyed in the Sandy's record 1964 flood.

“the north bank of the Sandy just upstream from Brightwood showed no indication of buildings, vegetation or topsoil where a group of 40 houses existed prior to the (1964) flood.” - U.S. Army Corps of Engineers Portland District Post-flood Report July 1966.

The 2011 flood caused significant erosion impacts along the river's shorelines, as well as to public and private infrastructure in developed areas. In the Upper Sandy, several houses were destroyed due to undermining of bank soils underlying house foundations. A half mile section of Lolo Pass Road serving hundreds of residents was washed out and bridges were threatened. Damages to roads and bridges from erosion forced temporary road closures and diversions, inspections, and costly repairs.

Evolution of the Sandy River Valley Reset during Eruptive Periods of Mt. Hood

So, what makes the Upper Sandy River behave the way it does, and with such frequency?

The Sandy River originates high on Mt. Hood, a glaciated Cascade Range Mountain. Mt. Hood is a volcano that has been active as recently as 150 years ago. Volcanic emissions over the last 2000 to 3000 years helped create the unstable foundations of the river we see today. The location and climate of the upper basin affect the frequency with which major flood events occur.

Alpine glaciers that have come and gone over the last 60,000 years carved out the Sandy River valley from volcanic bedrock. The current Sandy River watershed has evolved from a series of volcanic events, with its current form produced by deposition and surface erosion over the past 1,700 years. Lahars (also called volcanic mudflows) have been a key to the Sandy's formation, delivering rapidly flowing masses of ash, cinder, and rock fragments mixed with sand carried down slopes by steam and hot water during eruptions. The most recent lahar flows, which occurred around 1,700 and 200 years ago, have exerted profound controls on Sandy River behavior and the evolution of its valley. The 1,700-year-old event, called the Timberline Lahar, originated at



Figure 3. A twenty foot high section of the river's right bank (Sandy RM 40.8) illustrates that homes located well above the zone of flood inundation face serious risks of erosion. The bank is composed of Old Maid mudflow deposits from the 1800s, consisting primarily of sand easily eroded by the Sandy River.

Crater Rock on the upper southwest slope of Mt. Hood and flowed down the Zigzag and Sandy River valleys all the way to the Columbia River. About 1,500 years later another lahar, called the Old Maid Lahar, also originated from Crater Rock, but flowed down and inundated only the Sandy River valley. (Figure 4).

Each lahar event filled the valley with sediment ranging from a fraction of a millimeter to 2 or more feet in diameter. Following each event, the Sandy re-formed at the top of the lahar deposit and began to cut downward through the sediment layer. As it cut downward, the channel would widen

and begin to move back and forth laterally, a process known as channel migration (Figure 5).

After the Timberline Lahar, the river channel cut downward and widened by eroding the smaller, more movable sediments of the lahar deposit. The channel would have continued to down cut to the pre-Timberline elevation, but the Old Maid Lahar interrupted its progress. The Old Maid Lahar refilled the valley (Figure 5), forcing the Sandy River to reform at the top of the deposit, and began the whole process all over again (Figure 4).

Since the Old Maid Lahar event, numerous small lahars and debris flows consisting of older lahar sediments have coursed down the mountain slopes and through the Zigzag and Sandy River valleys. With each event, sediment builds up the valley bottom and the channel floor, raising the elevation of the stream bed and stockpiling thousands of cubic yards of sediment in large river bars, available for future downstream transport. Ultimately, the growth and subsequent erosion of these bars plays an important role in dynamic channel behavior, often dictating where erosion will occur.

The Upper Sandy River is continuing to adjust to the last lahar event and the large volume of sediment deposited within and adjacent to the channel. These adjustments usually take the form of bank erosion driven by channel migration, and channel avulsion, which take place during high flows. Channel avulsion is a form of migration where the river abandons its current channel to occupy a

newly formed, or older abandoned channel. The avulsion can take place abruptly during a single storm event or gradually over a period of several storm events. Avulsions occur when the current channel fills with sediment, or when flow is diverted out of the main channel by some combination of sediment and large woody debris, whose volume is sufficient to obstruct flow. A key point here is that channel migration and avulsion are both driven in large part by river discharges that are strong enough to move sediment and erode banks.



Figure 5. Forest in the lower Sandy River at Oxbow Park, buried by Old Maid mudflows about 200 years ago, emerged when the 2011 flood eroded the banks.

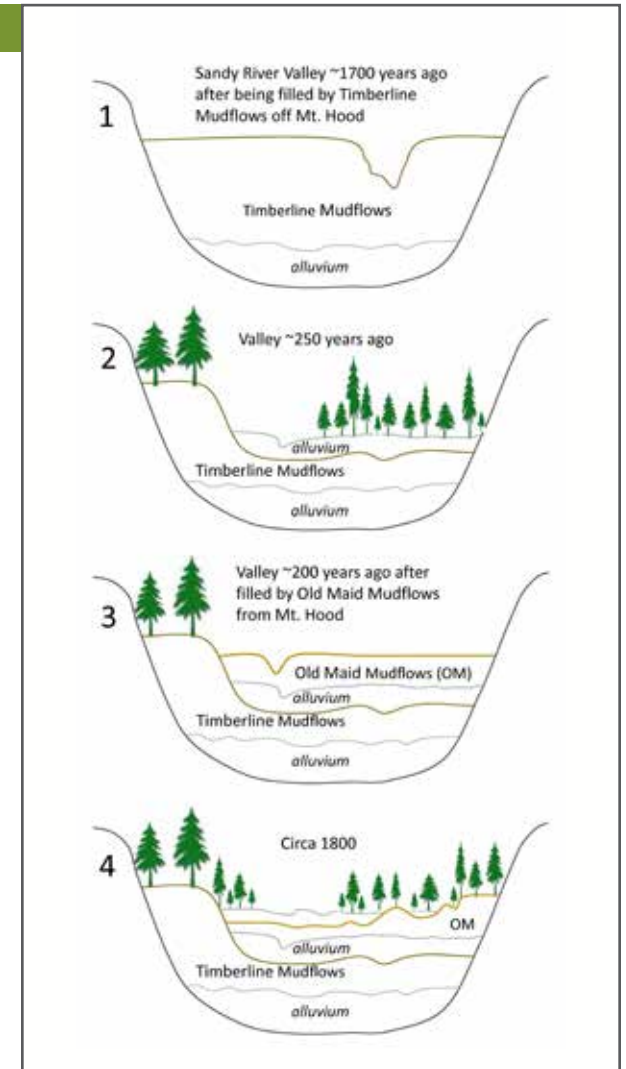


Figure 4. A simplified geologic history of the Upper Sandy River valley over the last 1700 years. The river lies within a glacial valley on Mt. Hood that was filled during mudflow during the mountain's Timberline eruptive period (1700 years ago). After the mudflows, the river would have rapidly eroded down, followed by a slower period of valley widening. During the Old Maid eruptive period ~200 years ago the valley was filled again by mudflow deposits. This was followed by downcutting and widening of the valley. Human actions have slowed natural valley widening and thus created more erosive conditions than would otherwise exist.

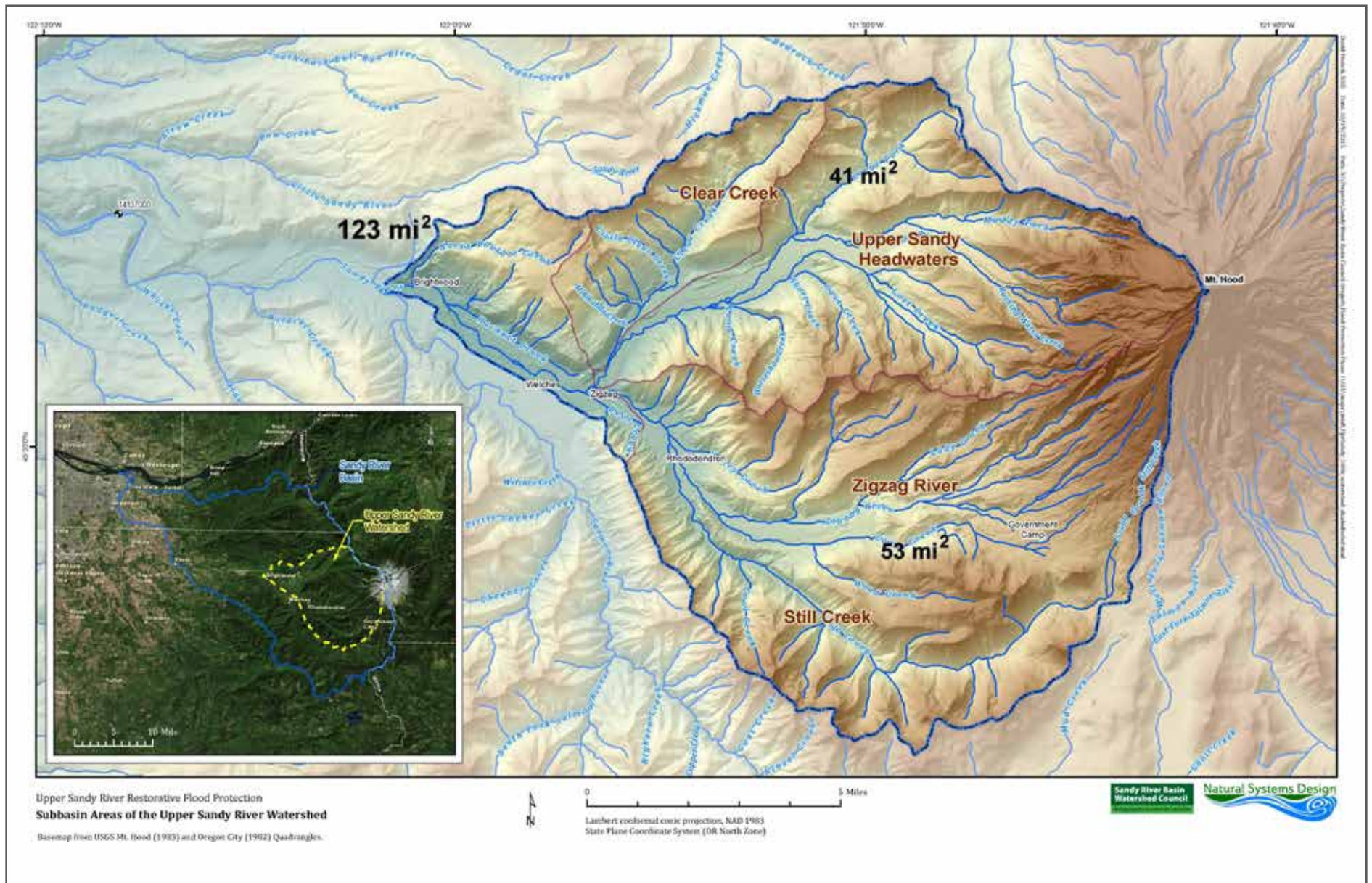


Figure 6. The Upper Sandy River watershed drains 123 square miles of the western flank of Mt. Hood. The Zigzag and Upper Sandy are the two primary tributaries that merge at Sandy River Mile (RM) 43.

Catching the Atmospheric Wave

The Upper Sandy drains the wettest side of Mt. Hood (Figure 6). Seasonal fluctuation in the Pacific Northwest climate changes the river's character dramatically through the year. Flow in August can be so low that parts of river won't be deep enough to float a raft, but come winter the river's flow can increase a hundred fold, rapidly turning into a raging torrent.

In the ten miles upstream of the Salmon River confluence (river miles 37-47) the Sandy drops 800 feet. In this ten mile section the river's gradient goes from 2% above the Zigzag River confluence (river mile 43) to 1.3% downstream (Figure 7a and 7b). This rapid change in the river's gradient profile means that this portion of the Upper Sandy is particularly responsive to changes in water and sediment inputs from the steeper upstream river reaches. A steeper channel gradient means a higher flow energy. High flow volume, coursing through a steeply graded channel increases the power of the river. The quantity of water depends on the magnitude of a storm, and at times how much snow had accumulated within the watershed when a storm arrives. The very largest storms capable of causing regional impacts are called atmospheric rivers because of the huge quantities of water they carry. They can bring on torrential rainfall for days at a time. The common term used for these storms, Pineapple Express, refers to their origin in the equatorial Pacific Ocean. Typically, large storms experienced in the Pacific Northwest occur between

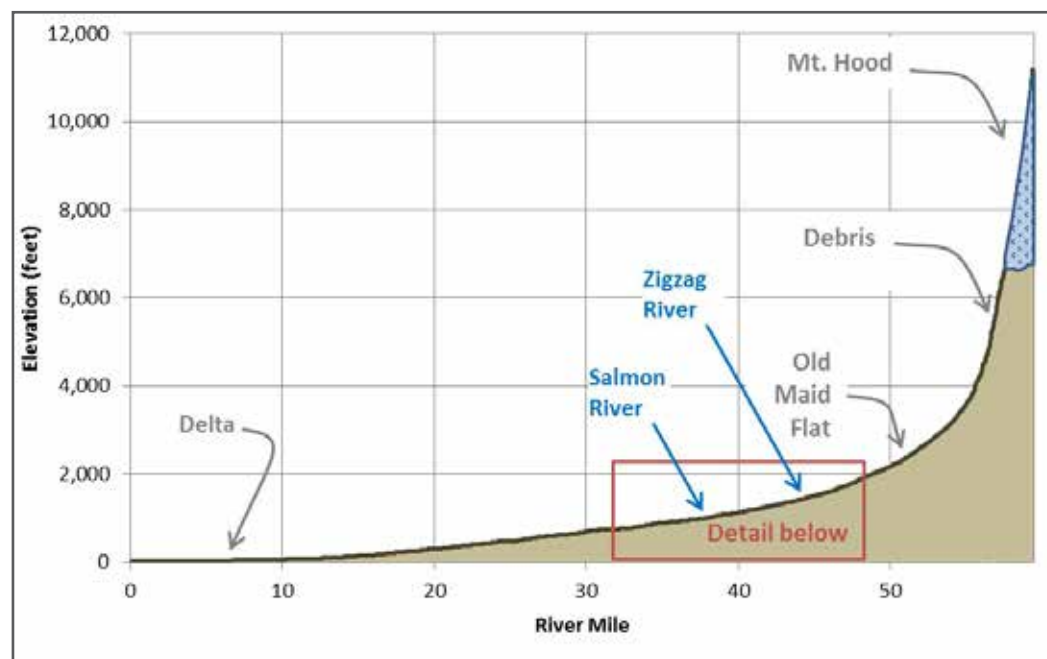


Figure 7a. Sandy River profile from summit of Mt. Hood to its confluence with the Columbia River. The river descends about 5000 feet in 57 miles.

November to January, when snow pack can be thick and lower elevation soils are already saturated from nearly constant rainfall.

At any given time, volcanic sediments can fall into the river channel through slope failures, debris flows, and bank erosion. Truly large sediment volumes are often supplied during and just after major storm events. Upon entering the river, the sediment load will travel more rapidly through steeper channel sections.

When incoming sediment volumes exceed the river's ability to move sediment downstream,

referred to as sediment transport capacity, the excess material is stored in the river as gravel bars, which redirect the current and drive channel migration and bank erosion. When there is less sediment in the river, a condition called "hungry water" is created and the river is likely to rapidly cut into its stream bed.

If all the elements required for migration/avulsion are present (stored sediment, heavy precipitation on snow deposits, confined channels) then river channel can shift substantial distances, up to hundreds of feet within the short duration of a single large storm.

Stream Power Meets Movable Landscape: Bank Erosion and Channel Migration

Upper Sandy River dynamics are driven primarily by three major elements: lots of water, abundant sediment, and very steep terrain. Several other elements and processes also contribute to the river's dynamic behavior including the sensitivity of river banks to erosion, the form of the channel (straight or with bends), whether the channel is confined by constructed levees and revetments, or the size and breadth of floodplains.

Channel migration usually takes place along river bends, when the outside bank of the river erodes and recedes while a sand or gravel bar develops along the inside bank of the bend. Migration is an important natural process by which the river channel disperses energy from high flows.

The Upper Sandy's erosive power is greatest where it is confined by high banks and constrained to a single, straight channel. In contrast the wider the river's floodplain, the greater the flood conveyance and energy dissipation, which allows the river channel to increase its length by forming a more sinuous path and creating secondary channels.

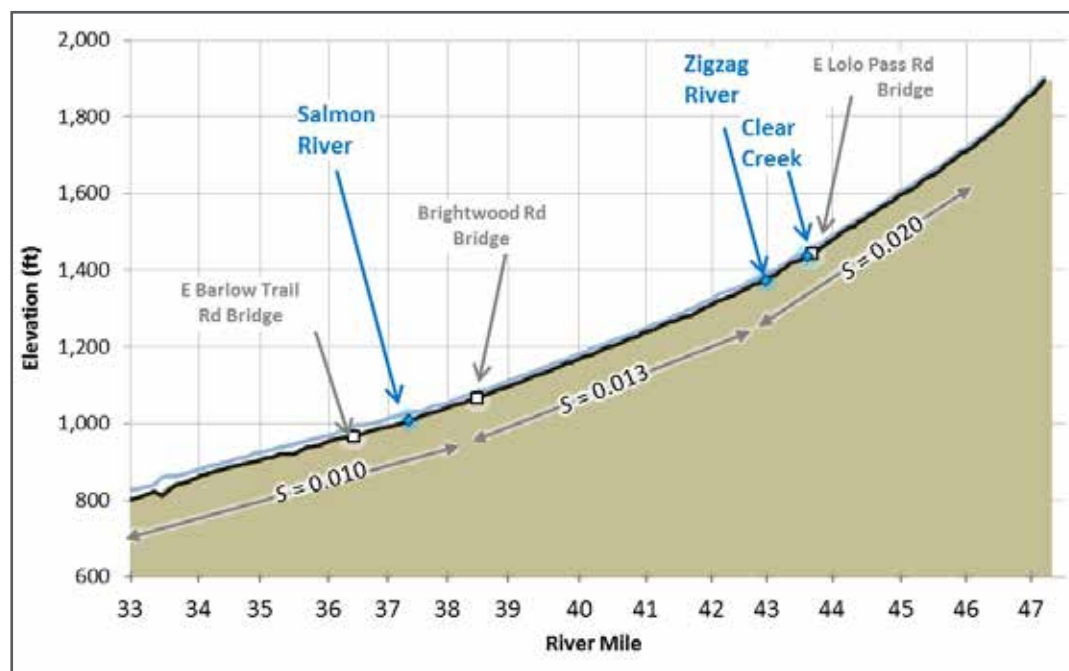


Figure 7b. The Upper Sandy River profile showing slope or gradient of the river. The river has a slope of approximately 1.3% from the Zigzag River confluence River Mile 43 (RM) downstream to RM 38.5, where it drops to about one percent. Upstream of the Zigzag confluence, the river's slope increases to two percent. In the 10 miles from the Zigzag to the Salmon confluence, the Sandy descends over 800 feet.

As high water disperses over floodplains, it slows down, spreading out energy that could otherwise cause erosion. Trees and vegetation further slow the flow of high water, and their roots hold the underlying soil together. When banks erode, fallen trees can form logjams that further diffuse the river's energy, and even protect some areas of floodplain from erosion. Given more space, the river would not only create valuable fish and wildlife habitat, but storms might deliver considerably less erosive power.

Human actions to constrain the river and armor its banks have slowed the natural channel widening adjustments of the river to the Old Maid Lahar. Constructed bank hardening structures prevent erosion and channel migration, and do little to slow flow energy. In fact, these structures often increase flow velocity and pass, unaffected, stream power downstream. In these places, most storm flows will scour the river bed, undercutting even formidable streambank structures.

Salmonid Habitat Requirements

What do fish need and how do they benefit the ecosystem?

Anadromous Fish Life Cycle

Wild salmon are adapted to the conditions and fluctuations of snow fed rivers like the Sandy. Salmon and steelhead are anadromous- meaning they are born in freshwater rivers and streams, swim as juveniles to the ocean to live most of their lives in salt water, and return to freshwater to spawn toward the end of their lives. To survive the perilous path from mountain streams to ocean and back, salmonids need a few conditions that together represent diverse, complex, and high quality habitat.

The Sandy River basin provides such critical habitat for wild salmon and steelhead at the beginning and end of their lives. A key component of proper salmon habitat is cool, clean water. Salmon begin to be stressed at temperatures above about 65 degrees F, and cannot survive in temperatures above 70 degrees F. Cool temperatures are driven by the source of the water (mountain glaciers and groundwater recharge), as well as forest cover around streams that provides shade to maintain cool temperatures.

Juvenile Salmon

Another key element of healthy habitat stems from the river's floodplain areas, especially areas away from the main flow known as off-channel and side channel habitat. To conserve energy as they move from spawning streams toward the sea, juvenile salmon need places where they can feed, rest and grow before they migrate to the Pacific Ocean. Channels off the main river are ideal habitat for them, especially during high water events when the Sandy River is roaring. They prefer cold, clear water that isn't flowing too fast but has lots of oxygen. Food is important, too. Young salmon need to grow larger to survive their journey to the ocean. Logs in the channel help create pools where aquatic insects, plankton, and invertebrates can live, providing salmon food sources. Side channels vegetations and log jams also provide adequate protective cover for young fish from predators.

Spawning Adult Salmon

Female salmon require specifically sized gravel to lay their eggs. This ensures that they are



protected from predators and oxygenated during development. When the female reaches a desired location, she creates a depression in the gravel with her tail known as a redd, and then deposits her eggs into the depression. She then waits for male salmon to fertilize her eggs before covering the eggs with more gravel to protect them. Incised rivers and side channels subject to high flow velocities often provide only limited, or degraded habitat because high velocity flows can remove, or prevent the deposition of, suitable gravel sizes for spawning.

Salmon Nutrients

Salmon die in the river shortly after spawning. Their decomposing bodies replenish nutrients rich in oceanic compounds, providing food for algae, invertebrates, and aquatic insects, which in turn feed juvenile salmon. Amazingly, these nutrients also enrich stream bank soils, and support the developed of riparian vegetation that provides shade to cool the river temperature and provide cover for salmon to hide.

When side channel and floodplain habitat disconnected from primary river systems, we lose functionality for our salmon, and disrupt this web of nutrients within our entire watershed ecosystem.

Sandy River Salmon: Threatened since 1999

Wild salmon and steelhead populations are currently well below their historic levels, so much so that they were listed as threatened under the Endangered Species Act in 1999 along with other Lower Columbia River populations. Scientific studies and modeling have identified what salmon need to recover, and helped us to re-evaluate the true impact of historic actions to reinforce (harden) stream banks against channel migration. Hardened river banks provide no habitat value. Confined channels limit habitat



Photo credit: USDA Forest Service

complexity and cut off areas that wild fish need to spawn, migrate, feed, and hide during high flow events. Changing the way we approach stream banks has the potential to turn peoples' responses to floods from a factor in salmon's decline into steps toward wild salmon recovery.

Channel and Habitat Responses to Bank Erosion

Channel migration and avulsion are natural and necessary river processes that can also have catastrophic consequences to aquatic and riverine habitat. In the Upper Sandy River, sections of river banks have been hardened by riprap embankments intended to prevent bank

erosion. Flow energy typically increases as it passes through these reinforced sections to unprotected bank sections further downstream, where it can damage banks and riparian zones as well as in-channel habitat and the built environment.

Confinement of the Sandy River also increases the river's ability to erode the material making up the river bed. The more energy the river has, the coarser its bed will be, as seen in the Upper Sandy River where the channel gradient is steep and the bed is composed of large cobbles and boulders. In this area, riverbanks, composed of relatively small material, are more likely to be eroded (Figure 8), regardless the height of the bank.

Close inspection of the rocks comprising the stream bed can provide a rough estimate of the local erosion risk. The diameter of boulders remaining in the river following high stage flood events can provide clues as to the size of rocks most likely to remain in place. In the Upper Sandy such rocks are over five feet in diameter (Figure 9). Recent studies have shown that the Upper Sandy is capable of moving boulders (rocks a foot or more in diameter). However, these same studies have also shown that, when given more space, the river's ability to move large material decreases dramatically. For example, where the floodplain is only 300 feet wide typical flows can move large cobbles over 10 cm (4 inches) in diameter. But in areas where the floodplain is 1100 feet wide typical velocities are half those in the more confined sections and the river can only move gravel 2-3 cm (1 inch).

The dramatic widening of the river that occurred in the Sandy's record 1964 flood had a similar effect in reducing the diameter of river bed materials. Instead of leaving behind a channel of boulders, the flood left behind large areas of gravel and sand (Figure 13). Left alone, channel expansion may have reduced future flood hazards and improved habitat. However, in 1965-66, the U.S. Army Corps of Engineers re-channelized the river on a massive scale throughout the Upper Sandy (Figure 13).



Figure 8. Home damage along the Upper Sandy River due to bank erosion. Note the bank is primarily composed of easily erodible sand whereas the river bed consists primarily of boulders. Photo: The Oregonian.

Flooding impacts can be devastating to people living along the river, although home owners can typically repair or rebuild if covered by flood insurance. Flood impacts typically range from minor land loss via bank erosion to the structural undermining of houses and infrastructure. These impacts were usually met with structures ranging from simple revetments consisting of riprap, to engineered levees, to crib walls constructed of large wood. Many of these treatments have had limited success or fail completely because they didn't extend deep enough into the river bed to prevent undermining. Structures have

also failed due to bank erosion at the upstream end and behind the structure. Once materials from the failed structure enter the river channel they represent additional potential downstream impacts, if stream flow can transport the material farther downstream. In addition to issues regarding the loss of bank structures, decisions made at single locations can have far-reaching effects on local and downstream flow velocity, erosion across the river and downstream and long term changes in river behavior. When a bank structure extends into the active channel, it can eliminate valuable cross sectional area by



Figure 9. Example of the six foot diameter rock needed to be stable in most of the Upper Sandy River (along left bank at River Mile 40.65 in July 2014). Even these rocks can roll into the river when the underlying material is washed away. Stable structures must extend below the river's scour depth.

Erosion and scour of the stream bed surface can alter both the composition of the stream bed and the its overall geometry, incising and simplifying the channel by smoothing out pools and riffles. These conditions degrade or completely eliminate in-channel fish habitat and prevent it from reforming. This process can remove sediment sizes useful to fish and other aquatic biota, leaving only large rocks and boulders.

In the Sandy, where the entire basin is the focus of priority habitat restoration efforts for salmon and steelhead listed under the Endangered Species Act (ESA), agencies and residents should recognize that hardened banks create no habitat value.

Removing levees that were built after the 1964 flood would help to increase conveyance, lower flood risks, and improve habitat (Figure 10). When the river migrates and expands, its length increases by developing a more sinuous channel with greater complexity and large trees eroded from the banks (Figure 12). These changes further diminish the river's energy by increasing its resistance to flow, in turn reducing the river's erosive power and ability to move material. The common perception that floods "clean out" a channel can be quite the opposite from reality. When a flood creates a wider channel it often creates a much more complex channel, with healthy fish habitat that better accommodates and diffuses the energy of the next flood.

narrowing and constricting the active channel. High energy flow deflected from a hardened bank can result in increased velocity (especially at high flows) and substantial erosion well

downstream of the treated bank. Results can include loss of bank line property, channel floor incision and substantial damage to aquatic habitat.

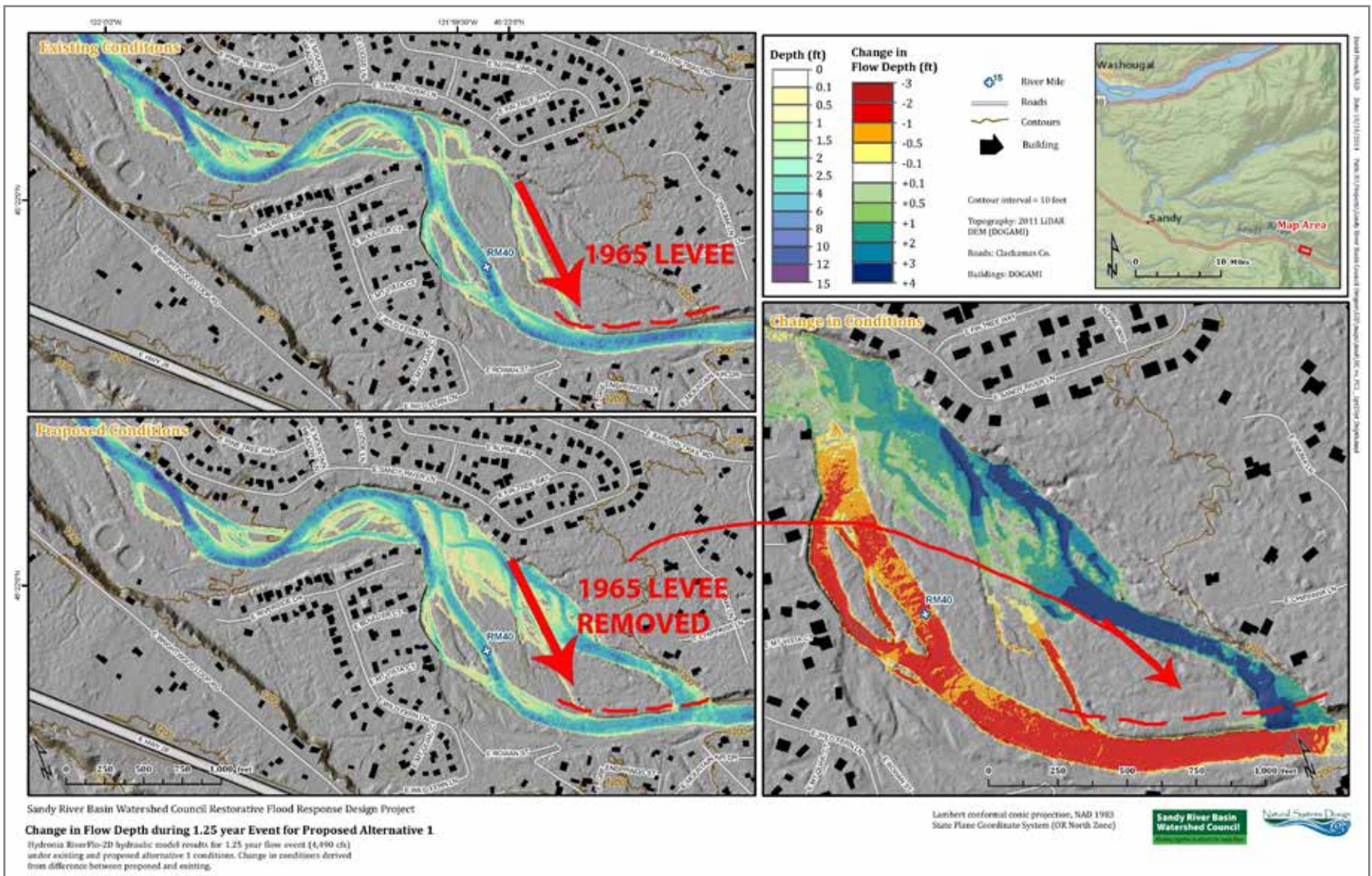


Figure 10. Modeling river levels illustrates how widening the floodplain area available to floods will diminish high flows associated with erosion and channel migration. The illustration shows modeled flow depth during a typical storm under existing conditions (upper left), and with a portion of the floodplain reconnected by removing a levee (lower left). The change image (right) compares flow depth with and without the levee in place, with red and orange indicating shallower flood levels. Re-connecting a channel that formed in the 1964 flood (and was cut off behind a levee in 1965) would reduce flood depths downstream by 3 feet.

Climate and the Sandy: Issues for the Future

Projected changes in our global climate likely will affect several elements that drive channel migration and large storms in the Sandy River Watershed. Records show that some climatic changes have already affected the Sandy. Since 1893 temperature has increased 1.8 degrees F and precipitation has increased 3 percent.

Comparing the first 50 years of the Sandy's documented record (through 1962) with the second 50 shows a 70 percent increase in the magnitude of the 100-year frequency flood.

Increasing temperatures predicted for the next 50-100 years indicate that freezing levels are rising. Precipitation that now falls as snow will fall as rain more often, and over a greater area within the Sandy watershed (Figure 11),

as the freezing level rises over time. Climate modeling suggests that by 2080, the region could see the area of rainfall and transient snow grow by nearly 30 percent. Lower spring snowpack, potentially reduced by over 80 percent by 2080, would reduce June flows by 60 percent, and possibly increase January flows by 40 percent.

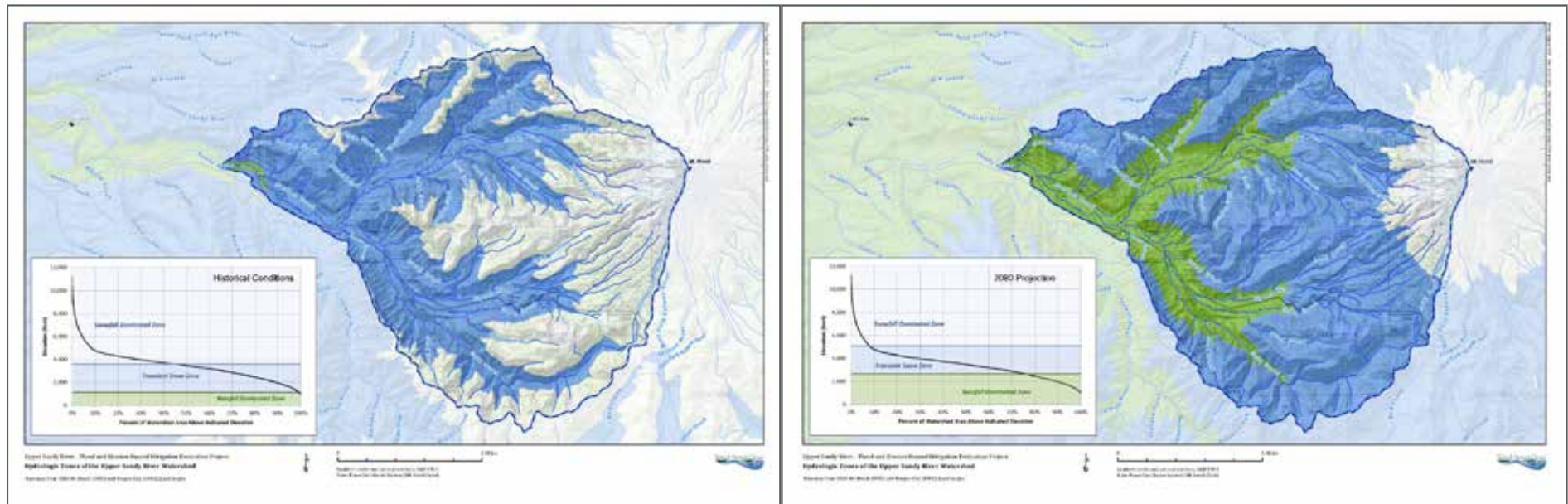


Figure 11. The warming climate is likely to intensify storms driving the Sandy's erosion and channel migration. Maps of current precipitation zones (above) and projected conditions (below) show an increase in the portion of the basin that receives most precipitation as rainfall (green area) and mixed rain and snow (blue) with the snow-dominated area shrinking significantly. Regionally adjusted climate models anticipate an increase in the extent of rainfall within the upper Sandy River of up to 24%, decrease in snowfall dominated area from 45% to 8%, and increase the transitional zone, where mixed rain and snow fall range from 54% to 68%. The net result likely will be greater quantities of runoff and higher peak flows in the river, together with greater sediment production from retreating glaciers in the Sandy's headwaters. As a result of projected warmer temperatures and higher freezing elevations, the Sandy's 100-year flood is predicted to increase 20% in the next 50 years. Colors -- green = rainfall dominated; blue = snow/rain mix; white = snow dominated.

In combination with higher freezing level elevations in the Pacific Northwest, climate models project increasing frequency and intensity of atmospheric river ('pineapple express') storm events. This combination of factors will increase flood magnitudes.

Predictions are that by 2099, 100 year floods could increase by over 200 percent in frequency, and grow in intensity between 16-38 percent. Climate warming is also accelerating the retreat of glaciers on Mt. Hood and elsewhere. The projected increase

in rain-on-snow events in the Sandy watershed also indicate an increase in the volume of sediment delivered to River and tributary channels from valley walls and the edges of receding glaciers.



Figure 12. Along a road washout in the Upper Sandy River after the 2011 flood, large wood scattered and lodged along the river, increasing roughness and complexity of the channel. Historic confinement and clearing of the river has prevented the river from spreading out and dissipating its erosive energy. The more space the river has, the lower the river's erosive power. Allowing the river space to move and connect broader floodplains not only reduces flood risk, but expands salmon habitat. Photo by PGE



Figure 13. The the U.S. Army Corps of Engineers moved an astounding amount of flood debris in response to the December 1964 flood, here they are re-building the pre-flood channel, confining miles of the Sandy between levees, and stripping off streamside vegetation. Note the fine grained material of sand and gravel. The wide expansion of the river channel and its floodplain that occurred in the 1964 flood left behind large deposits of fine grained material not found in segments of the river that are constrained. The finer substrate not only reflects a less erosive river, but is much more beneficial to salmon. Where the river is allowed to migrate and widen its floodplain, it will create a more sinuous and multi-thread channel that is more effective at dissipating energy and creating more desirable fish and wildlife habitat. (Photo courtesy of the Arrigotti family and Clackamas County)

Assessing Risk

Risk affects both the Sandy River ecosystem and people who have property or infrastructure within a hazard area. The ecosystem evolved within the context of natural disturbances that included floods, erosion, and catastrophic mudflows. Native trees and vegetation help to stabilize the landscape by intercepting rainfall, adding cohesion to the soil and dissipating the river's energy after trees fall into the river. Risk is defined as the probability of an event

occurring and the consequences it will have. For example a 100 year flood (one percent chance of occurring in any year) can cause a lot of change.

The 1964 flood had a low probability it would occur, only about a 0.4 percent (~250 year flood) chance, but one that carries immense impact, and thus a high risk due to its consequences. Because the Sandy's banks can erode even in moderate events, the probability of bank failure

increases (Figure 14). Over the last century (1914-2014) about 550 acres have been eroded by the river along a ten mile segment of the Upper Sandy (RM 37-47). In some areas, the maximum rate of erosion was almost 25 acres per year.

The more development that has occurred in areas impacted by floods, the greater the consequences and the greater the exposure to risk. Areas of the Upper Sandy developed since



Figure 14. Tree roots can help stabilize banks by adding cohesion, but only to depths of about three feet and thus can be undercut along high banks. A traditional rock revetment (Sandy RM 39.5) is visible in the right background. The relatively smooth surface of these types of traditional bank stabilization structures can intensify erosive energy along natural banks, creating a condition where the structure can accelerate its own demise. Revetments such as this one temporarily slowed river's natural expansion toward its pre-floodplain prior to the Old Maid mudflows. The wider the floodplain, the more the river's erosive power is reduced. Allowing the river space to move and create new floodplain not only reduces flood and erosion risk, but enhances salmon habitat.

1964 have created high risk conditions in which flood impacts and dramatic channel migration are likely to occur on a regular basis.

While risk is typically viewed in a human context, it also applies to native ecosystems (Figure 15). Development that constrains natural processes like flooding can have severe consequences to the ecosystem on which salmon depend. Flood driven changes we perceive as hazardous can be very productive for fish and wildlife that have adapted to these processes. Functioning floodplain areas are not only ideal for conservation and recreation, but can dampen downstream flood peaks and protect water quality. Limiting development impacts in floodplains creates conditions that are safer for people and the ecosystem.

Risk is also involved in constructing flood protection structures such as bank revetments aimed at stopping erosion. To be durable, structures must withstand all the forces the river can impose on it and the changes the river will undergo. Revetments can fail because they simply weren't built to withstand the full power of the river. Using naturally occurring structures, such as logjams, as models, new engineering approaches have been developed to offer restorative alternatives. Structures such as engineered logjams can be used in some circumstances to reduce the risk of bank erosion while also creating valuable salmon habitat.

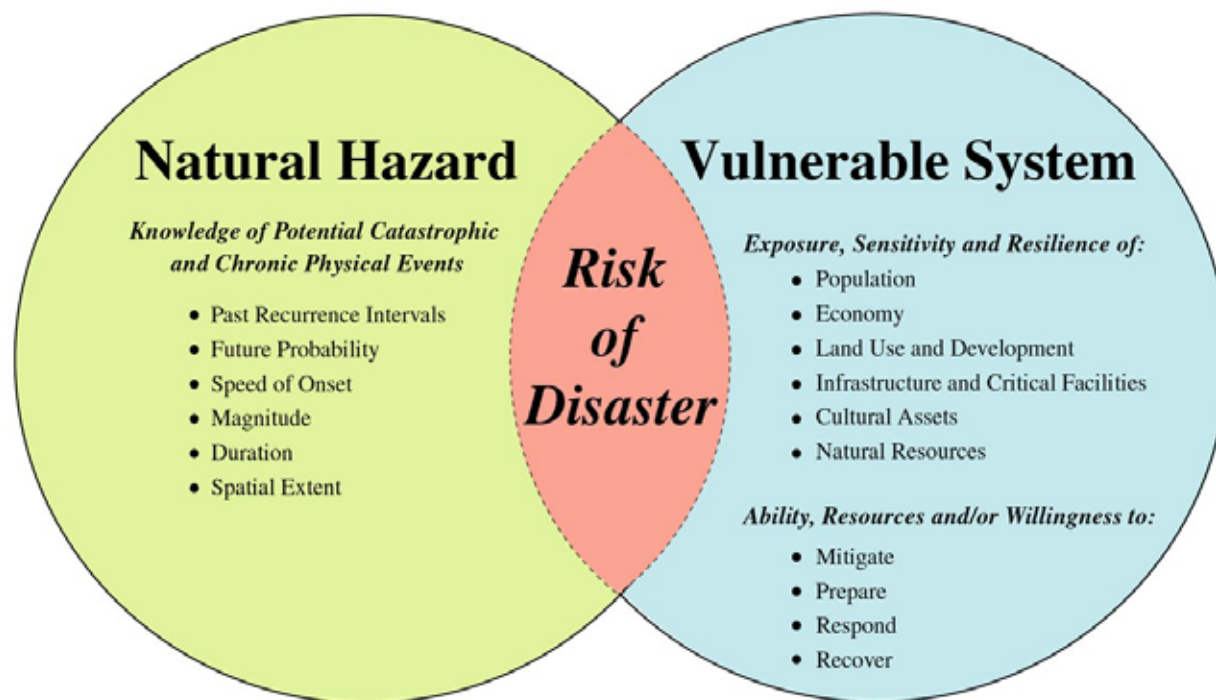


Figure 15. Risk is a function of natural hazards and vulnerable human systems. Source: Wood, USGS 2007

Engineered stream bank structures require a sound understanding of river characteristics and dynamic trends. Collaborative actions across multiple properties can help to reduce risk, create positive habitat benefits for sensitive species, and acknowledge the impacts of our actions on those around us. Neighbors along a river reach working

together can avoid actions that would create a “slingshot” effect of pushing the problems of erosion or river force downstream or across the river. Working together, within an understanding of the Sandy’s forces and channel migration process, Restorative Flood Response actions can have a greater chance for success.

Toward Restorative Solutions

It is possible to reduce flood and erosion risk in the Upper Sandy in ways that enhance fish and wildlife habitat and quality of life for people living in the Sandy River Basin. A relatively small number of residents are currently impacted by flooding and erosion, but over time, a much larger portion of the community will experience some type of impact in response to our changing climatic conditions. Developing habitat-positive, durable, affordable and equitable flood response strategies involves everyone in the community and those using infrastructure such as highway 26 or other access routes through the watershed.

Clackamas County has developed channel migration zone maps for the upper Sandy (see references), based on historic and recent aerial photos, LIDAR imagery, and analysis of river movement. The maps show areas of potential risk from future channel-migration, and other various risk zones .

The safest approach to navigating natural hazard areas is to avoid development within them. Avoidance is, in fact, the single most important action that can be taken. Any property within flood and erosion hazard area is ultimately unsafe for permanent dwellings, but holds great potential for fish and wildlife habitat and recreation.

One option landowners within hazard areas can consider is working with public agencies or land trusts to sell their land or relocate to safer areas. Actions by individual landowners can not stop the Sandy River from migrating. Individual actions can also adversely impact other landowners and reduce investment in long-term solutions that benefit the broader community.

An effective Restorative Flood Response strategy for the Upper Sandy consists of three elements:

1) **Give the river room (Figures 17 and 18)**

Future development decisions need to anticipate impact from channel migration, and work where possible to avoid placing buildings and infrastructure in identified high risk zones. Clackamas County's Erosion Hazard Mitigation Analysis recommends a minimum floodplain evolution zone (FEZ) of 900-1200 feet. Infrastructure and structures within the FEZ should where possible be relocated to safer areas outside the channel migration zone (CMZ). In cases where stakeholders are affecting streambanks or floodplains, Restorative Flood Response actions require a reach-scale, community-based approach, rather than property-by-property planning.



Figure 16. Illustration of how river restoration doesn't just benefit salmon, but also people. The photos above are looking upstream at same site before and after restoration of the Mashel River in Eatonville, WA. In 2006 a rock revetment was replaced by a series of engineered logjams. The logjams formed deep pools where none had previously existed and created greater textural variance in the channel. Over 400 juvenile salmon were documented in each of the ELJ pools and during the summer the pools became popular swimming holes for Eatonville residents.

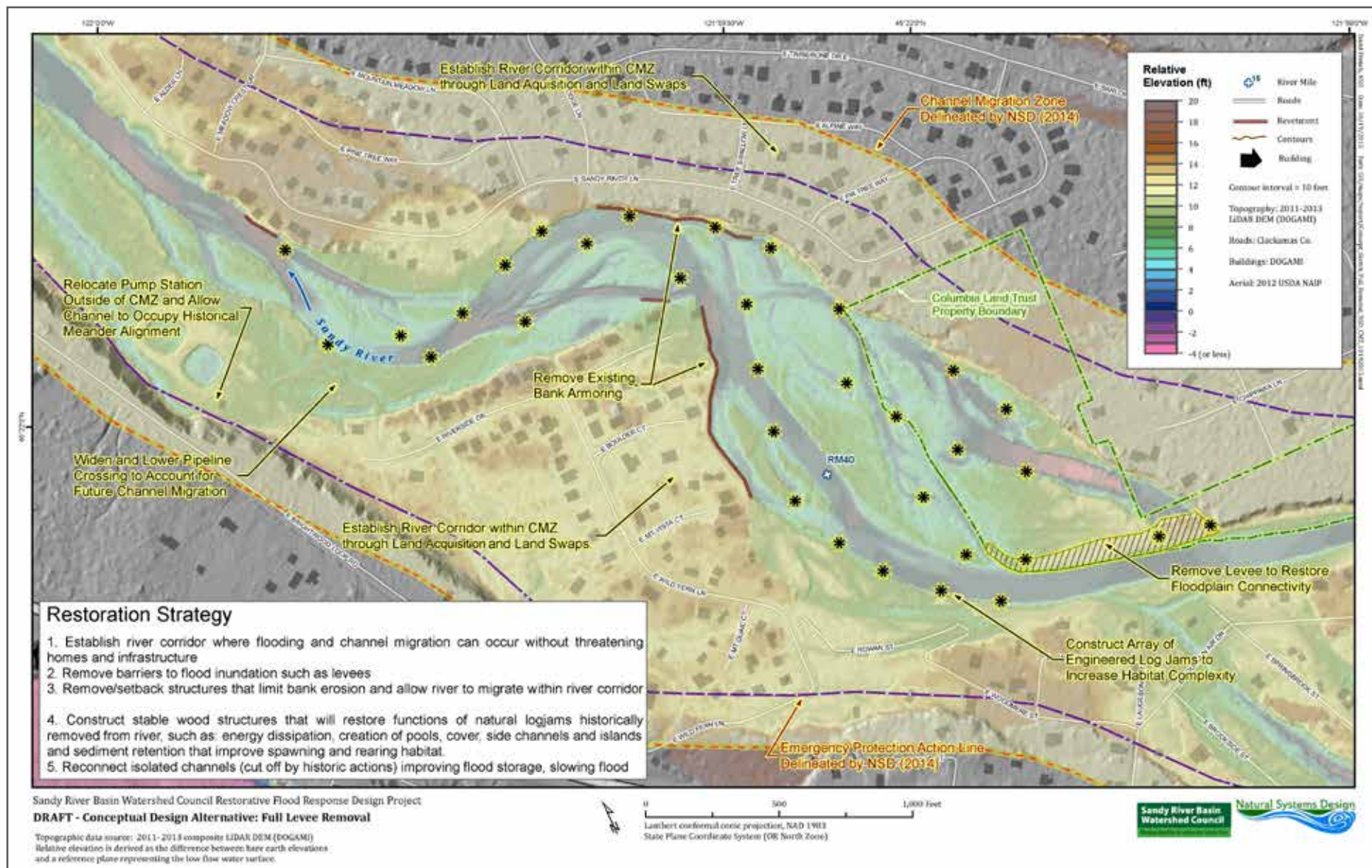


Figure 17. The conceptual plan in this illustration would create a channel migration zone where a neighborhood was developed following the 1964 flood, constructing an array of engineered log jams, and consider voluntarily relocating properties within the zone

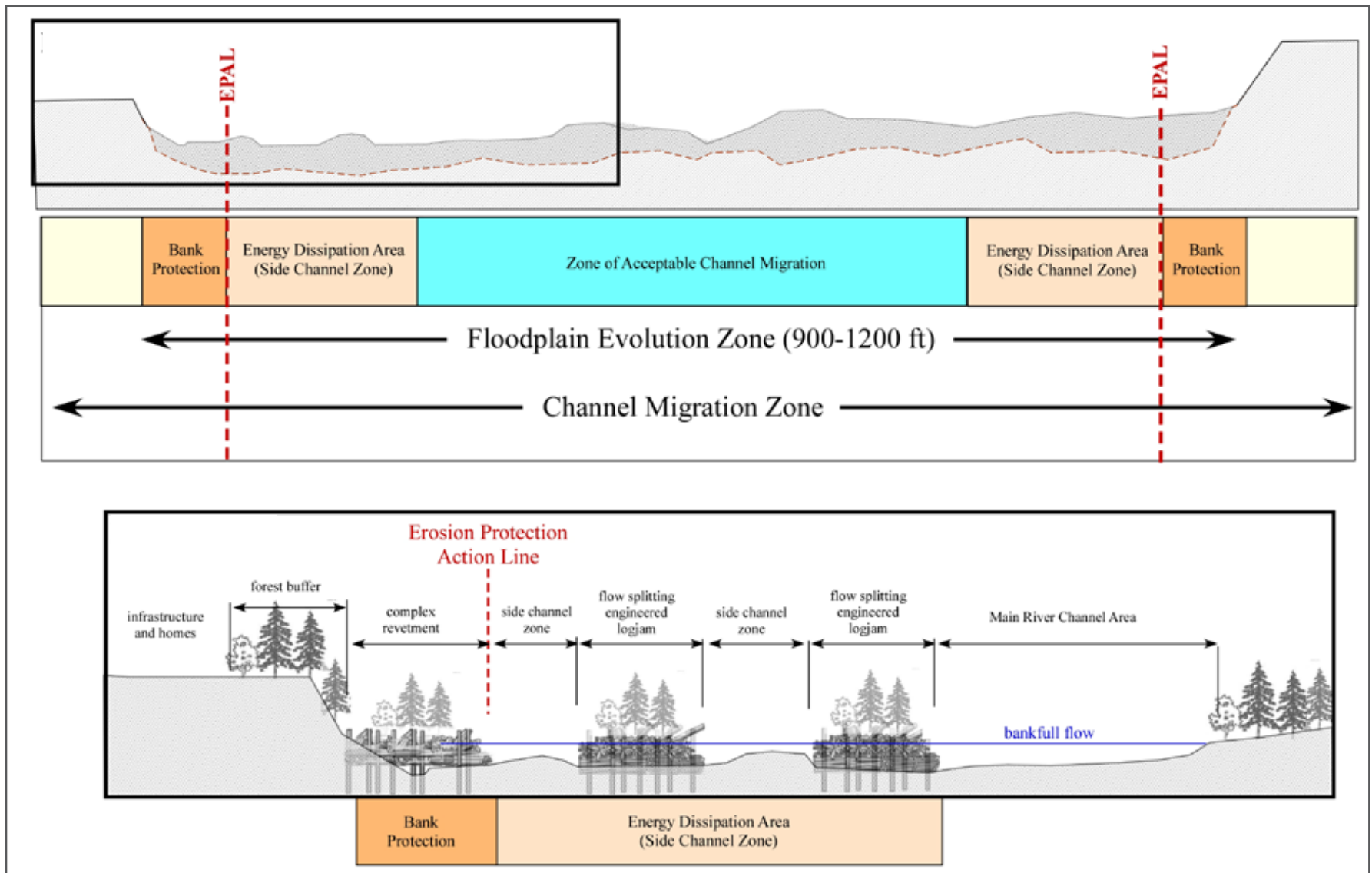


Figure 18. A conceptual valley cross-section illustrating a Restorative Flood Response strategy within the Channel Migration Zone. An area should be set aside to allow for natural channel migration and flood conveyance. At the margins, restorative flood response measures focus on dissipating energy while allowing flood conveyance into less erosive side channels. Roughened wood-based structures along the banks can reduce the river's energy and create additional fish habitat. Engineered log structures should be self-settling and deeply embedded into the channel to prevent damage due to scour and incision.

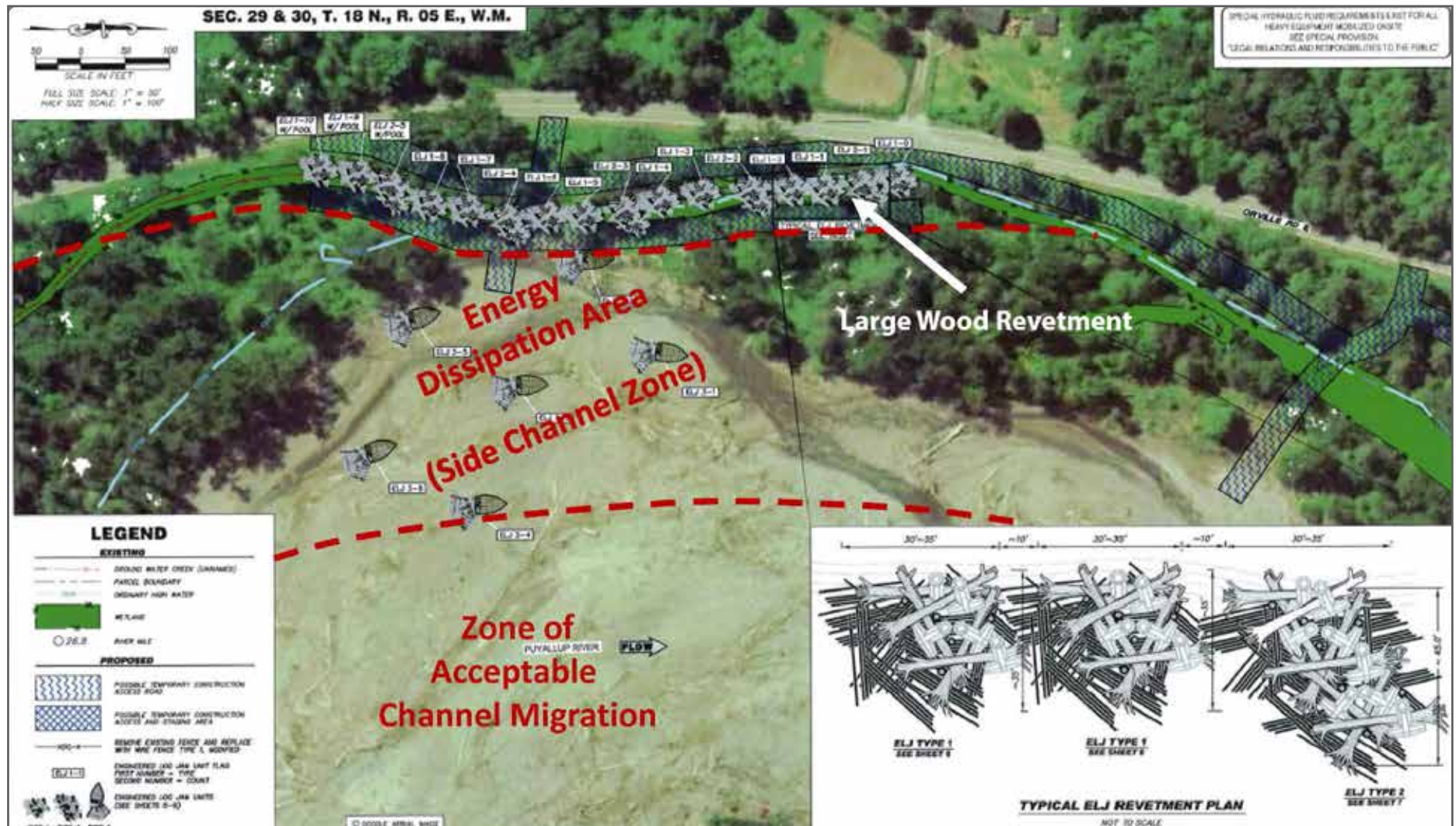


Figure 19. An example of large wood structures used to reduce erosion risk on a county road along the Upper Puyallup River, which drains from the western flank of Mount Rainier. Six engineered logjams (ELJs) were constructed in the energy dissipation area, a portion of floodplain that had previously been eroded by the river. The ELJs will establish forest islands and side channels that create salmon habitat while keeping the main channel away from the road.

2) Dissipate the river's energy with reconnected floodplains (Figures 19 and 20)

Re-connecting floodplains that were walled off by post-1964 flood levees would redistribute high flow energy from large storms across a broader area. Actions like this have the added benefit of expanding valuable habitat for wild salmon and steelhead. Constructing flow splitting engineered log jam structures that break-up the main channel flow into smaller “side” channels can reduce erosive energy downstream. This can be done by constructing an array of island forming engineered logjams (ELJs). Partitioning the river’s flow, particularly during storms, can provide flood conveyance and habitat but divert some of the river’s highest energy away from developed areas and infrastructure.

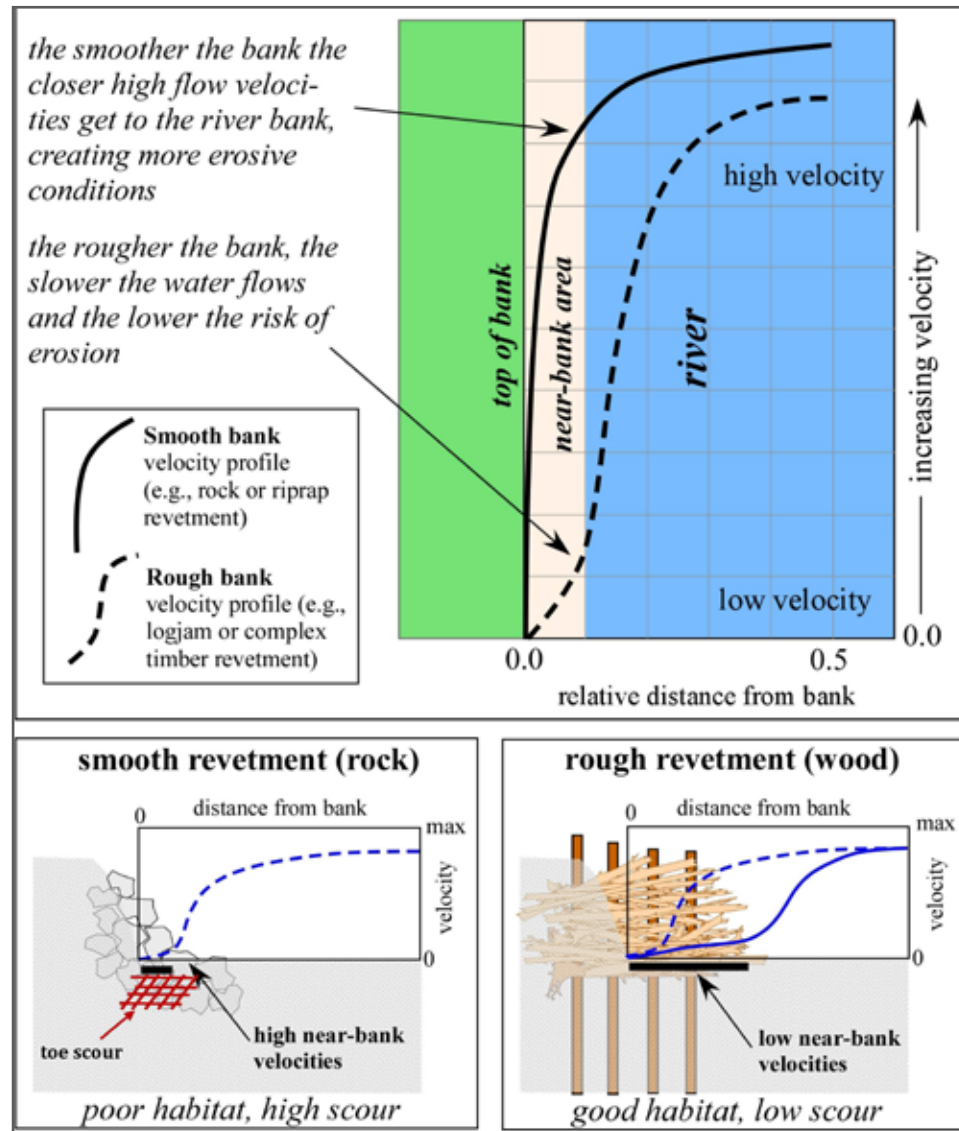


Figure 20. Illustration of how rougher banks reduce river velocities near the bank. Traditional bank protection tends to create a smooth bank where high flow velocities hug the bank (solid lines above). Where banks are roughened near-bank velocities are reduced (dashed lines), diminishing the risk of erosion and improving salmon habitat.

3) Seek salmon friendly stream banks (Figures 21 and 22)

Restoring and protecting mature native forest vegetation along stream banks helps to stabilize soils, create roughness during storm events, and support habitat conditions. Any stream bank intervention should consist of rough structures that dissipate energy and enhance habitat where the river cannot be permitted to migrate and where residents or agencies act to restrict erosion and channel migration.

Such structural interventions should aim to meet the following objectives:

- a. Reduce near-bank velocities.
- b. Strengthen the shoreline so it is less likely to erode.

Any structural intervention intended reduce erosion should be designed to create stable roughness elements within the river corridor (Figures 19 and 23). The primary role of these elements is to dissipate energy upstream of developed areas and infrastructure. Rough structures reduce near-bank velocities, thereby lowering the risk of erosion (Figure 20). Any stream bank structures should also strengthen the bank, making it more resistant to erosion. Complex roughness elements create low velocity interstitial area, which is ideal for juvenile salmon seeking refuge during floods, and provide year-round shelter for fish hiding from predators.



Figure 21. An engineered large wood revetment built by the Lummi Nation created a rough streambank very different than traditional rock revetments found along Sandy River. The structure along the South Fork Nooksack River in northwest Washington is stabilized with timber piles and rock collars.



Figure 22. Example of engineered logjam that doesn't have self-settling elements of previous examples. This structure is deeply embedded into the river so that it can withstand scour without being compromised. Note people on right side of the structure. Pit is 16 feet deep and timber posts extend deeper. Elwha River 2014.

Constructed streambank structures also need to be adequately stabilized.

The principal methods of stabilization involve:

- Creating a self-settling structure that sinks into the river bed when scour occurs. This approach requires ballast such as large boulders that interlock with the timber
- Deeply embedding the structure into the river using piles or excavating a deep pit during construction (Figure 23).

With more space to move around in, the Sandy River can develop a more sinuous channel (bends) and additional side channels or anabranches. These changes would add length to the river, which reduces its gradient and adds roughness, both of which reduce the river's erosive energy. Additional energy dissipation would occur with the installation, or natural formation of more logjams in the river.

Much of the Upper Sandy is currently a relatively simple boulder bedded channel in which deep pools and spawning gravels are rare. Allowed to migrate and increase its channel length, the river will develop an irregular bathymetry with deep pools and a finer texture and that will not only benefit salmon and aquatic wildlife, but also create summer swimming holes, sunny gravel bars, and great fishing.



Figure 23. The Upper Puyallup project during high flow in 2014 looking upstream at two of engineered logjams (ELJs) in the energy dissipation area (side channel zone). View is from complex large wood revetment on Upper Puyallup River's left bank. The ELJs are splitting flow into smaller channels before the flow reaches the bank. The ELJ is one of six forming an array of structures to keep the main channel from approaching the bank. Photo by Tom Nelson.

Getting Started in Your Neighborhood

Sandy River residents can follow a few basic steps toward exploring the potential for Restorative Flood Response where they live:

- Know your CMZ – look at the Clackamas erosion study and channel migration zone maps to get a sense of historic and potential future erosion risk at your own location along the river.
- Work with neighbors – identify areas where floodplain reconnection might be possible on or upstream of your own property
- Consider federal flood insurance – even properties outside the delineated FEMA floodplain can obtain flood insurance, and be covered for channel migration and erosion related damages. Anyone can voluntarily participate for HMGP and PDM funded buyouts, but only those with FEMA flood insurance can apply for Flood Mitigation Assistance, which is paid for by NFIP premiums.
- Consult with qualified professional engineers, and County permitting staff – before attempting any stream bank or floodplain intervention focused on reducing erosion on the Sandy. Consult with engineers who work on migrating rivers. The presence of endangered salmon in the Sandy may restrict what is allowed. Be aware that this dynamic river requires careful assessment of any action along its banks for both durability and potential unintended downstream effects.



SRBWC & NSD working with community leaders to discuss flood impacts and possible restorative flood response solutions. Photo by Corinne Handelman

If an area of concern has habitat value, the Sandy River Basin Watershed Council may be able to assist in evaluating potential actions,

and seeking technical and financial resources to help implement Restorative Flood Response Actions.

Additional Restorative Flood Response Resources

Upper Sandy Flood Erosion Hazard Mitigation Evaluation

Clackamas County contracted Natural Systems Design to study historic and potential future channel migration in a 10-mile reach of the Upper Sandy River basin. The detailed study, which includes maps of a hazard zone and broader channel migration risk areas, is available online:

<http://office.naturaldes.com/htcomnet2/Handlers/AnonymousDownload.ashx?folder=7bcda461>

Native Planting Guides

Native plants may help reduce streambank erosion, as their root systems extend deep into soils and help improve its strength. Tree species such as willow and Western Red Cedar thrive on stream banks and support an ecosystem of associated plants that are beneficial to riparian and floodplain habitats. For more information on native plants and their preferred conditions, see:

<https://www.portlandoregon.gov/auditor/34460?a=322280>

http://www.oregonmetro.gov/sites/default/files/native_plants_for_willamette_valley_yards_booklet.pdf

Dynamic River Restoration Disc

Through community discussions following the January 2011 floods, the Sandy River Basin Watershed Council assembled information into a CD disc titled “Restoration Resources for Dynamic Rivers”. This covers basic information about river systems and restoration techniques, with input from local experts.

The Restorative Resources for Dynamic Rivers material is available from the Sandy River Basin Watershed Council on CD, or on the web at:

<http://www.sandyriver.org>

Clackamas County Emergency Management

The County Emergency Management Program focuses on flood risk reduction and other localized hazards. Along with the erosion hazard study, the County has installed emergency flood gauges on the upper Sandy River at three bridge crossings to warn local residents about flood levels before they are read on the standard gauges further downstream. Information for these and other resources can be found online:

<http://www.clackamas.us/emergency/flooding.html>

Federal Flood Insurance

Clackamas County provides information on applying for flood insurance at the following link:

<http://www.clackamas.us/emergency/floodinsurance.html>

Land Trusts

Several non-profit land trusts operate in the Sandy River Basin and may be able to assist landowners willing to sell land with habitat value along the river corridor. Contacts are below:

Columbia Land Trust

511 SE Morrison St.
Portland, OR 97214
503-841-5918
www.columbialandtrust.org/

The Nature Conservancy

821 SE 14th Ave
Portland, OR 97214
503-802-8100
www.nature.org/ourinitiatives/regions/northamerica/unitedstates/oregon/

Western Rivers Conservancy

71 SW Oak Street, Suite 100
Portland, OR 97204
503.241.0151
www.westernrivers.org/ | info@westernrivers.org