Erosion Management Guidebook

Chehalis Basin Strategy

By

Anchor QEA

For the

Office of Chehalis Basin
Washington Department of Ecology
Headquarters Office
Lacey, Washington

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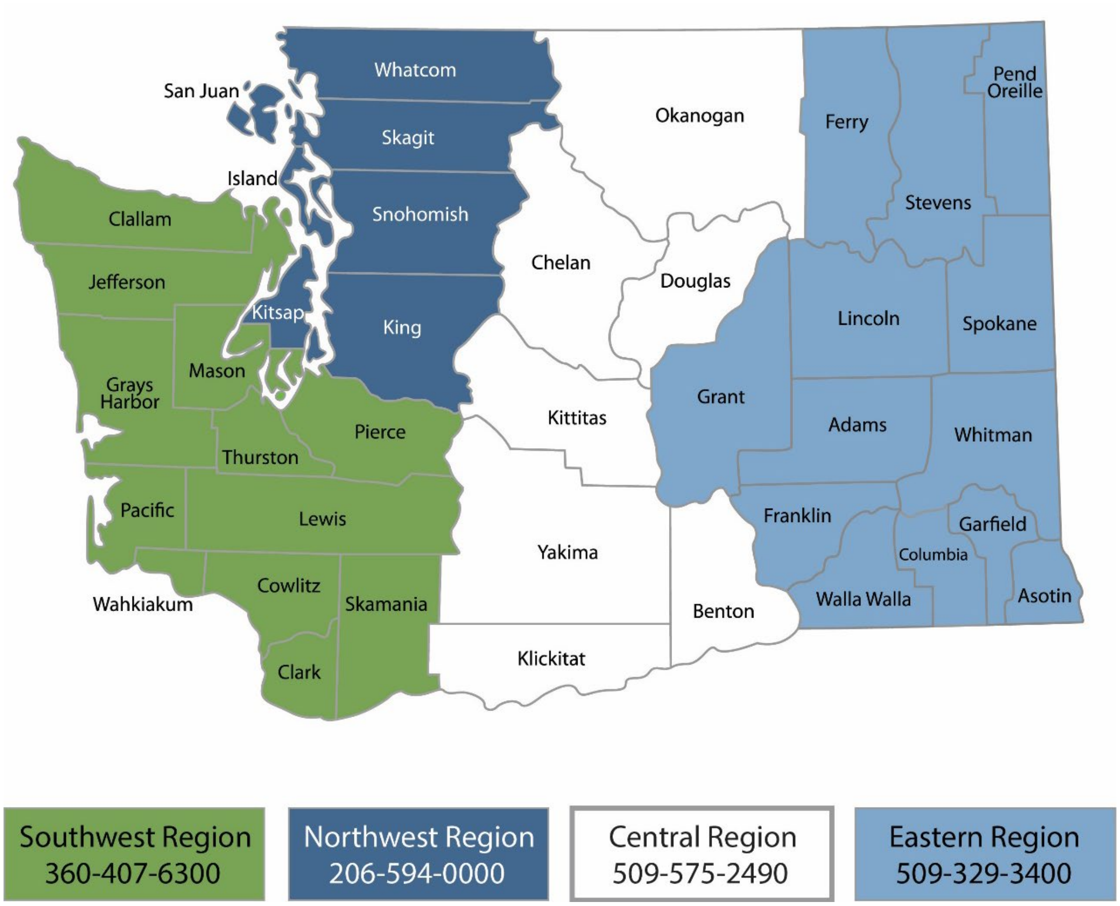
Department of Ecology's Regional Offices

Map of Counties Served



Region	Counties served	Mailing address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

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Scientific Dictionary

avulsion	the sudden change in the path of a river from one location to another
bioengineering	the use of natural materials including wood, soil, and plantings (sometimes with the limited use of rock) in an engineered design
channel migration zone	an area in a floodplain where a stream or river channel can be expected to move naturally over time in response to flow, soil conditions, and topography
deflection	to turn aside or in another direction (e.g., to turn the water flow or energy away from a stabilized bank)
floodplain	an area of low-lying ground adjacent to a river and formed mainly of river sediments and subject to flooding
fluvial geomorphology	the study of how rivers form patterns on the landscape from the combination of moving water and the materials of the streambed and banks
impervious surface	surfaces, such as buildings or pavement, that allow essentially no water to infiltrate into the ground
runoff	the draining away of water from the surface of the land, usually then entering a stream or other waterbody

1. Erosion Management Guidebook Overview

Using this guidebook

This Erosion Management Guidebook was developed to help Chehalis Basin landowners, residents, and contractors identify soft shoreline techniques that can be used immediately or in the long term to address concerns about bank erosion. Hard shoreline techniques such as placing rock or concrete are strongly discouraged because they cause negative impacts to aquatic and shoreline habitats and can increase erosion on neighboring properties.

Please take the following steps if you are experiencing stream or riverbank erosion that threatening structures, utilities, or other infrastructure, or if you are losing valuable land:

- Contact your local county conservation district (see **Appendix A** for contact information).
- See **Chapter 2** and **Chapter 3** to understand what may be happening on your site and available funding through the Chehalis Basin Erosion Management Program.
- See **Chapter 4** to see what will be needed to obtain a permit for an erosion management project.
- See **Chapter 6** for soft shoreline solutions that can be put in place at a site while minimizing effects on fish and wildlife and shoreline habitats.
- **Appendix B** provides a checklist of important things to look for on your site when considering what solution may be needed.
- **Appendix C** provides a more comprehensive list of types of soft shoreline (or bioengineering) techniques.

For more information about erosion management program funding and the Chehalis Basin Strategy, visit chehalisbasinstrategy.com.

Frequently asked questions

Q: What should I do if an adjacent river or creek is encroaching on my property and endangering my home or other infrastructure?

Please reach out to your county conservation district (see **Appendix A** for contact information) to provide more information and schedule a site visit on your property.

Q: Is adding rock the most effective way to stabilize an eroding bank?

In the short term, placing large angular rock or boulders can help reduce erosion along a stream or riverbank a singular location. However, large rock and boulders do not naturally occur in much of the Chehalis Basin and can cause unintended and undesirable effects on adjacent properties and the river environment. This is because rock placement creates a new “hard point” that refocuses the water’s energy to other locations. This can increase erosion or have other unintended impacts on other upstream or downstream locations.

Additionally, it is common for local scour or toe erosion to form, creating a scour hole at the base of the slope. Over time, the rock placement will be eroded beneath and fall into the scour hole, destabilizing the rock slope and necessitating more rock placement. Because of this common cycle of failure over time, rock is not a desirable permanent solution for erosion management. Large angular rock also typically has large spaces in between rocks where water can enter and erode behind the rock. In areas that are flood prone or have high bank erosion rates, high water may get to the back side of the slope and cause bank failure behind the rock placement. More information on these erosion mechanisms is provided in **Chapter 2**.

Q: How does rock placement impact river processes, riparian conditions, and aquatic habitat?

Rock placement is a short-term solution to respond to bank erosion by redirecting the energy of a river. Placing rock, however, can also inhibit or change natural processes such as reducing the lateral migration of the channel. Channel migration helps bring coarse sediments and wood into the river system. Both provide important habitat and flow diversity for salmon and other aquatic life that rock typically cannot provide. Large rock does not provide a suitable surface for native vegetation—for example, large trees growing on riverbanks provide cover and shading for the aquatic environment. Natural bank erosion, often inhibited by rock placement, also creates undercut banks and deep pools that are important habitat for aquatic life, especially during the summer when water levels are low and temperatures are high.

Q: Is bioengineering more expensive than using rock?

Bioengineering is the use of natural materials in an engineered design, such as deliberately adding wood to a stream and planting new shoreline vegetation. This approach can often be less expensive than using rock and may reduce maintenance over time. Instead of deflecting water to other locations, engineered log jams and new vegetation help reduce a river's energy by allowing the water to strain through. Mature vegetation and wood helps strengthen the riverbank.

Q: How long does bioengineering last?

Bioengineered projects become more integrated into the bank and form a more natural bank over time and most remain fully functional for 25-50 years or more. Maintenance is usually required in the first few years to ensure the plants become established (such as watering) and to manage invasive species.

Q: I've never seen or used bioengineering—how would I know what to do?

This guidebook is designed to help you identify suitable bioengineering techniques for your property. **Appendix C** and the references listed on page 4 also provide more detail.

Q: Do I need a permit to install bioengineering?

All projects involving work below the ordinary high water line in a river or along the marine shoreline require permits from federal, state, and local agencies. Some agencies also may require a permit for work above the ordinary high water line. See **Chapter 4** for more information.

Q: Can someone assist me to complete a bioengineering project?

Yes, the erosion management program provides funding to assist Chehalis Basin residents address erosion problems. The program provides a pathway for a "project sponsor," such as a conservation district, city, or county, to help submit applications for funding and develop and implement projects. See **Chapter 5** for more information.

Overview

Erosion is a natural process in which soil, rock, and other materials move from one location to another across the landscape. Erosion can benefit riverine and shoreline environments. However, in the built environment, erosion can also cause problems, especially when buildings and other infrastructure are built in the natural path of the river meander, also called the channel migration zone.

The Chehalis River basin (**Figure 1**) and many of its tributaries have altered flow patterns and geomorphology due to land use changes from development and attempts to slow bank erosion. In recent years, many rivers and streams in the Chehalis River basin (**Figure 1**) have experienced high rates of bank erosion during winter storm and flood events. While this guidebook primarily focuses on river and streambank erosion, it can also be used to address erosion concerns along the Grays Harbor shoreline.

The Washington Department of Ecology's Office of Chehalis Basin and the Chehalis Basin Board oversee the development and implementation of the Chehalis Basin Strategy to reduce damages from major floods and restore aquatic species habitat. We have funding to help landowners reduce erosion damages while minimizing harm to aquatic habitats. Where possible, our goal is to improve aquatic species habitat through restoration actions. This guidebook provides helpful information on bioengineering techniques that incorporate natural materials such as wood, soil, and plants that can stabilize a streambank, manage erosion and improve aquatic habitat.

The cities and counties within the Chehalis Basin have adopted shoreline master programs that include specific requirements to protect critical areas such as river and marine shorelines as well as buffer areas. Most shoreline master programs require any bank stabilization projects be designed so projects do not cause problems at other upstream and downstream locations. The shoreline master programs require a geotechnical report to show why bank stabilization is necessary and strongly encourage bank stabilization projects be designed using soft stabilization methods using wood and new vegetation planting. Hard methods deploying rock or concrete are only allowed when no other option is possible (e.g., Thurston County 2023; Grays Harbor County 2020; Lewis County 2021).

Detailed information about soft stabilization methods can be found in the following references:

- *Integrated Streambank Protection Guidelines* (Washington Department of Fish and Wildlife 2003)
- *Engineering with Nature: Alternative Techniques to Riprap Bank Stabilization* (Federal Emergency Management Agency 2023)
- *Guidance for Stream Restoration* (U.S. Department of Agriculture 2018)
- *Stream Restoration Design* (Natural Resources Conservation Service 2007, adopted as Part 654 of the *National Engineering Handbook* [Natural Resources Conservation Service 1996])
- *Streamside Planting Guide* (Washington State University 2015)
- *Soft Shoreline Stabilization: Shoreline Master Program Planning and Implementation Guidance* (Washington Department of Ecology 2014)

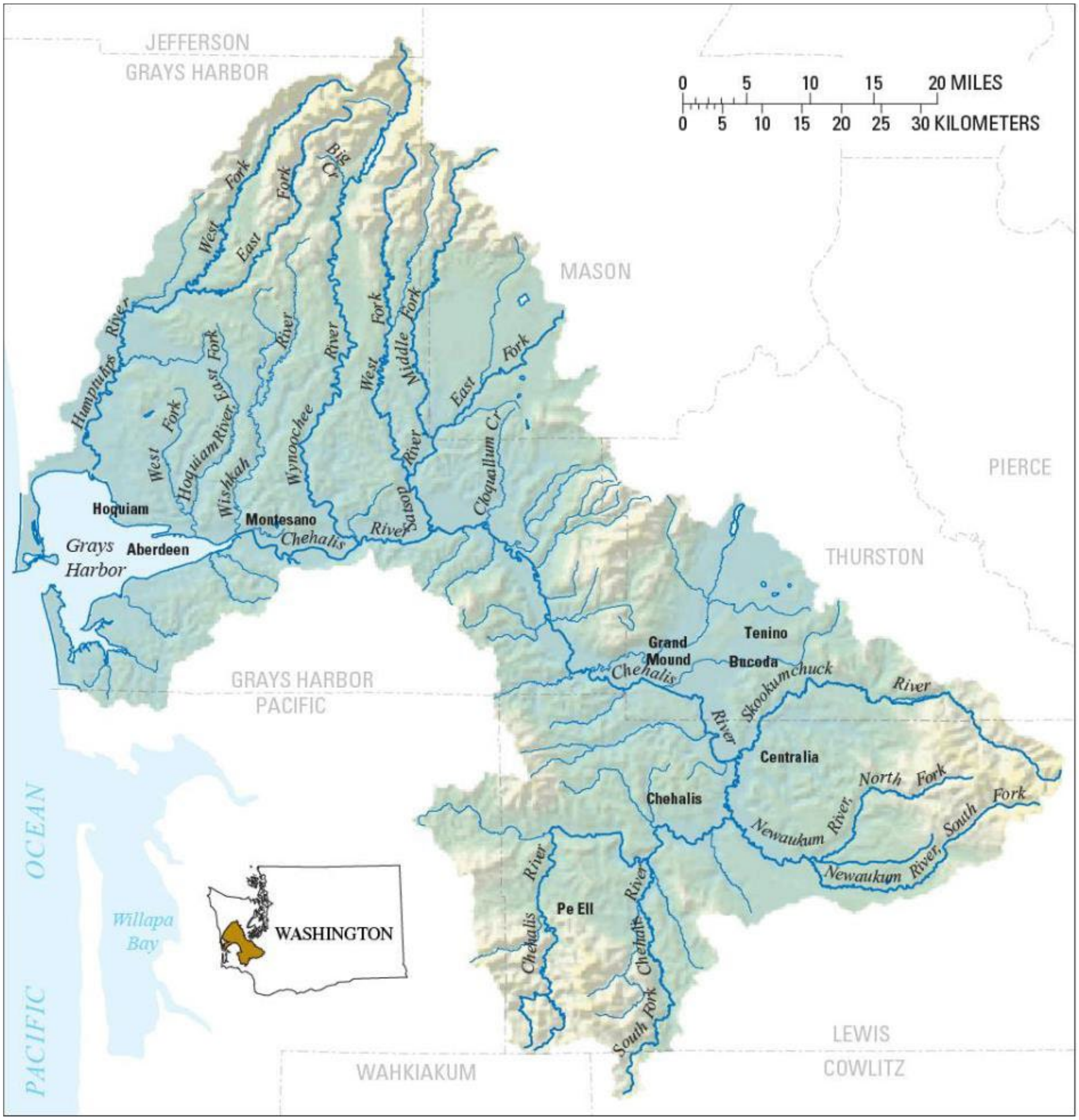

Figure 1. Chehalis Basin watershed

Bank erosion is a natural process. It is beneficial to aquatic environments because it delivers important materials like gravel and wood into the stream system and forms new habitats, such as side channels. A stream’s most productive and diverse habitat exists along the shoreline, where the land and water habitats meet and intersect. This interaction involving water, sediment, wood, and vegetation helps create channel and shoreline structure and contributes to ecosystem complexity, diversity, and connectivity that support salmon and other aquatic life.

The Chehalis River basin formed the current landscape through channel migration and avulsion (rapid channel change to new location) over thousands of years. **Figure 2** is a colorized version of the existing bare earth landscape, showing where the main river channel has moved over time.

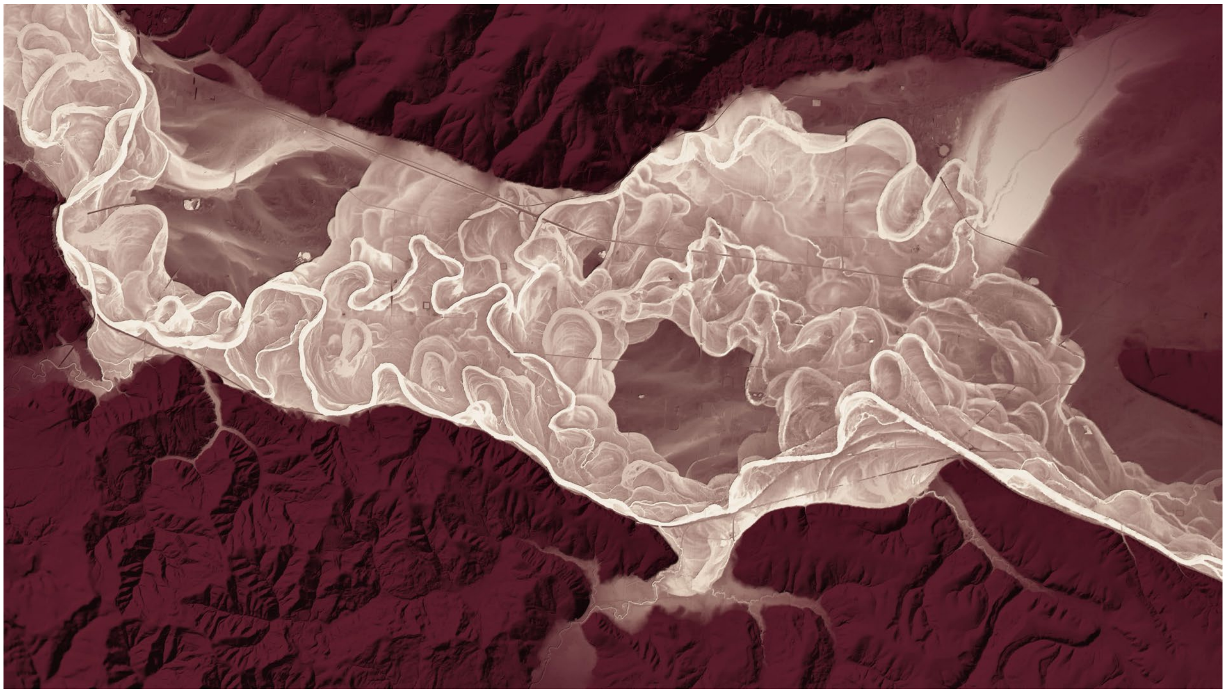

Figure 2. Historic Chehalis River channel locations (at Black River confluence)
Source: Daniel E. Coe, Washington Geological Survey, Washington Department of Natural Resources.

Although bank erosion occurs naturally, human activities along a river can accelerate the processes related to erosion and sediment deposition. Bank instability and erosion can threaten infrastructure such as roads, houses, barns, or buried pipes and tanks. Activities that can cause bank erosion and instability include removing vegetation, concentrating water flows (e.g., drainage pipes) that expose bank surfaces, increasing impervious surfaces such as paved driveways, roofs, and sidewalks, and excessive irrigation. Individual landowners have the responsibility to understand how their actions affect bank erosion, channel migration, and channel stability.

In addition to human activity, there are several physical processes that can cause erosion within the Chehalis Basin. Toe erosion, local scour, mass wasting, and bank seepage are natural dynamic erosional processes that occur due to normal river and shoreline currents as well as receding flood flows.

Mechanisms of erosion

Evidence that erosion is occurring at a site does not necessarily mean that it must be managed because each site is unique. Variables such as rate and severity of erosion, avulsion potential, future channel migration zone, and possible threats to existing infrastructure or valuable working lands must all be considered. **Chapter 3** outlines how to conduct a site assessment, and **Chapter 6** discusses potential erosion management techniques.

Common Chehalis Basin erosion mechanisms are as follows:

- **Toe erosion**
  - The toe is located at the bottom of the bank between the streambed and average water height.
  - Toe erosion occurs when river flow removes particles from the streambank and/or the immediately adjacent streambed. This eventually undercuts the overlying bank and the bank collapses.
  - Oversteepened banks form from collapsing bank materials. Toe erosion is cyclic and often reoccurs on newly steepened banks.
  - Bank failure typically occurs when silty or clay soils that can hold a relatively steep slope are undercut.
  - Toe erosion may initiate larger landslides in locations with steep hillsides.

Figure 3. Evidence of toe erosion at bottom of riverbank

- **Local scour**
  - Local scour is erosion at a specific location that occurs on the streambed or into the bank that is greater than erosion found at other nearby locations.
  - Local scour occurs when flow encounters a natural or human-made obstruction or hard point that redirects the energy of the flow to a location less resistant to erosion.

- Consequently, the stream flow increases in speed. The increased flow speed has a higher erosive force, and it moves the streambed or bank sediment at a higher rate than it would without an obstruction.
- Local scour appears as tight scallops along the bank or as depressions (for example, a pool) in the streambed.
- This mechanism is often the source of deep pools surrounding large woody material. Pools are an essential habitat feature for salmonoid species. They use the pools for resting and feeding.

Figure 4. Local scour below root wad logs installed along riverbank

- **Mass wasting**
  - Mass wasting is the large-scale movement of rock and soil down a slope under the influence of gravity. Rock falls, slumps, landslides, and debris flows are all examples of mass wasting. Mass wasting events can provide large quantities of sediment to a river or even temporarily block the channel, leading to avulsion risk.
  - These large landslides are commonly triggered by heavy rainfall on disturbed slopes.

Figure 5. Evidence of mass wasting of slope along riverbank

- **Bank seepage**
  - Water seeping out of streambanks can wash soil particles away, causing the upper part of the bank to collapse. The movement of soil particles by seeping water through the ground is called piping, which can create hollows in the bank face.
  - Common sources of water flow are natural groundwater flow, agricultural and stormwater drainpipes, and irrigation runoff (Hagerty 1992).
  - Bank seepage is not a common mechanism of failure in the Chehalis Basin; however, it can be observed after a prolonged high flow in a river that has fully saturated the bank drains down. This may occur downstream from dams that maintain high flows on a river for a prolonged period, such as to release water from behind the dam after a heavy rainstorm.

Figure 6. Seepage cavities observed along riverbank (yellow circles)

2. Background On The Chehalis Basin Environment And Factors That Contribute To Erosion

Past and present land uses

A variety of intensive land uses have occurred in the Chehalis Basin over the past 150 years, including forestry, agriculture and urbanization. y Activities that reduce forest canopy cover can increase the rate at which precipitation reaches the soil, potentially causing higher peak storm flows in streams and rivers, as well as the deliver sediment from hill slopes. Removing riparian or streamside vegetation can also reduce the strength of the bank and allow more surface runoff to enter streams and rivers. Impervious surfaces from urban and rural development also increases peak stormflows. These types of land use practices can increase sediment deposits into streams and rivers, further directing river flows into channel banks. A combination of land use practices has resulted in confining rivers and increasing storm flows, accelerating erosion in the Chehalis Basin.

Riparian vegetation

The riparian zone is the land immediately neighboring both sides of a stream or river. A healthy riparian zone generally consists of native vegetation such as grasses, willows, cottonwoods, cedars, and other native shrubs and trees (**Figure 7**). Riparian vegetation help dissipate stream flow and energy, which protects the surface and channel banks from erosion. Vegetation protects streambanks in several ways:

- Root systems help hold soil particles together, increasing bank stability.
- Reduce the speed of water flowing against channel banks and across the floodplain.
- Promotes transported sediments to deposit by slowing down flowing water.

A vegetated riparian zone offers more than bank stability. Vegetation help filter out bacteria and pollutants. They provide food and habitat for wildlife, shade to promote cooler temperatures, and provide habitat for insects and other food for aquatic life.

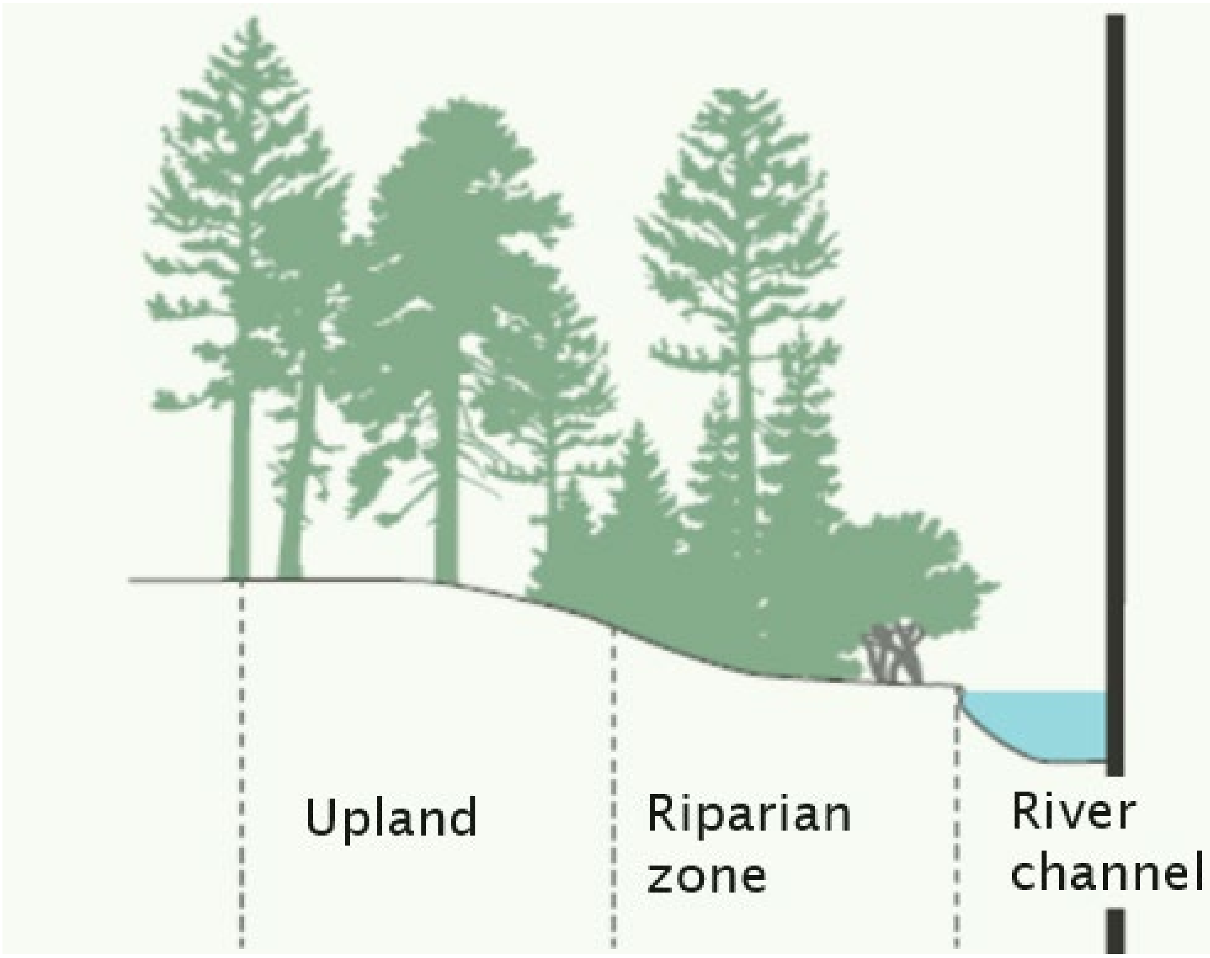

Figure 7. Zones within river corridor
Source: Adapted from Washington Department of Fish and Wildlife 2021.

Native vegetation such as willows, cottonwoods, alders, western red cedar, dogwood, salmonberry, sedges and rushes are preferred in the riparian zone. A list of typical native riparian plants in the Chehalis Basin can be found in **Appendix D**. Non-native plants like invasive knotweed, reed canary grass and blackberries are harmful to riparian zone. Planting and maintaining existing native trees and shrubs while removing invasive weeds can help ensure a healthy riparian zone that also reduces rates of erosion. **Appendix D** includes a list of invasive weeds and contacts for support.

Hydrology

Flooding is a natural condition and floodplains along rivers help to slow and store floodwaters and allow the water to seep into the groundwater table, supporting habitats and stream flows. However, climate change is contributing to more frequent and intense winter storms and floods events in the In the Chehalis Basin. Five of the Basin's largest recorded floods, including the highest flood of record, have occurred in the last 30 years. There is an anticipated trend toward more intense and frequent rain events, and less snow accumulation. In the lower basin, sea levels are rising.

More frequent flooding can have many negative effects on residents, public infrastructure, agriculture, and other land uses. River and stream flows resulting from heavy rainfall often have high velocity and can erode streambanks, transport large wood, and move sediment along the streambed. These storm events can also lead to increased landslide risk because heavy wet soils on exposed hillsides and riverbanks are more likely to collapse or slide.

Geology

The Chehalis River basin has been shaped by a unique geologic history, including volcanic and sedimentary rock and both glacial- and river-deposited material. Riverbank materials found in many parts of the basin are easily eroded, including a variety of loam, silt loam, silty clay loam, and sandy loam soils found in floodplains and natural terraces next to rivers. These soils are primarily fine materials and erode more easily than a streambed composed of gravel and cobbles (**Figure 8**).

Over time, river and stream channels naturally move across a floodplain as water carves away at the channel banks. The combined effects of underlying geology, land uses that removed vegetation and confined rivers, and increased flood events and storms has accelerated the rate of erosion and channel migration in many of the Chehalis Basin.

Figure 8. Chehalis Basin bank erosion into agricultural field (mainstem Chehalis River)

3. Site Assessment

A site assessment is the first step in understanding an erosion concern as well as identify environmentally appropriate techniques for erosion management. You can also request assistance from your local conservation district or Washington Department of Fish and Wildlife. (see **Appendix A** for contact information). While several erosion management techniques recommended for the Chehalis Basin are discussed in **Chapter 6**, is it important to know the physical conditions present at your site and identify the why the erosion is happening before selecting an erosion management technique. A site assessment checklist is provided in **Appendix B**. In addition, the following should be considered when completing the site assessment to help identify and select the most appropriate erosion management technique:

- Physical condition of stream or shoreline bank
- Location where eroding bank is failing (e.g., outside a river bend, straight section of the river)
- Recent flooding
- Extent of bank erosion upstream and downstream
- Location where bank is eroding (e.g., toe slope, upper bank)
- Duration and speed of erosion (e.g., getting worse, speeding up)
- Bank height and grade (steepness)
- Bank materials (e.g., silt, clay)
- Previous physical alterations (vegetation removal, previous stabilization techniques, bank excavation)
- Other neighbors also experiencing erosion challenges
- Threats to structures and farmland
- Location of new structure along the riverbank
- Location of ordinary high water line

4. Plans And Permits

Developing project description and site plan

Once you have identified why the erosion is occurring, you can begin to identify solutions and where to act. You may wish to contact your local Conservation District to help find a qualified professional (such as engineer, biologist, geomorphologist) to assist you in developing a plan. Permitting agencies will need a description of your project, which can be developed by describing what approaches are proposed in a site plan A good project description and site plan should clearly explain:

- Purpose and need for the erosion management project and consideration of relocating at-risk structures or other assets away from the eroding bank
- Proposed solutions and how the work will be done without pushing the problem up or downstream
- Steps to avoid or minimize impacts to fish, wildlife, or shoreline function, including identifying riparian vegetation to be removed or installed and methods used to reduce the potential sediment runoff
- What, if anything, will be installed below the ordinary high water line and the methods to be used for installation
- A vicinity map with project location; a plan view (top down) of the work; and one or more cross sections (side view) that clearly show the existing bank line, ordinary high water line, wetlands (if any), mapped floodplain, and dimensions of the proposed features

Permits

It is a landowner or project sponsor's responsibility to obtain all required permit before starting work on any erosion control management project. In most cases, several permits will be required, from federal, state, and local agencies. It is best to initiate the process several months in advance to allow for ample time to get all necessary permits in place. When it is necessary to protect human life and safety or stop the impending immediate loss of a structure, emergency permits or exemptions can be obtained from most agencies for temporary work.[2]

Potential permits needed for erosion management projects are as follows:

Federal Permits and Approvals

- Clean Water Act Section 404 Permit
  - U.S. Army Corps of Engineers
  - Discharge of dredged or fill material into waters of the United States (e.g., placement of rock or wood or excavation below the ordinary high water line)

[2] See more details in this focus sheet on emergency exemptions for shoreline stabilization: Focus Sheet Option 4 Template.

- 3 to 12 months
  - Smaller projects or those with minimal adverse effects to the aquatic environment can be permitted via a Nationwide Permit No. 13 (bank stabilization), which speeds up the approval process.
- Rivers and Harbors Act Section 10 Permit
  - U.S. Army Corps of Engineers
  - Any work in or over a navigable water of the United States that could affect navigation
  - 3 to 12 months
  - Typically permitted concurrently with a Section 404 permit.
- National Historic Preservation Act Section 106 Consultation
  - U.S. Army Corps of Engineers with the Washington Department of Archeology and Historic Preservation
  - Any ground-disturbing project with a federal permit or federal funding that has the potential to affect cultural, archaeological, or historic properties
  - 3 to 12 months
  - Approval is concurrent with a Section 404 or Section 10 permit.
- Endangered Species Act Section 7 Consultation
  - National Oceanic and Atmospheric Administration National Marine Fisheries Service and U.S. Fish and Wildlife Service
  - Any project with a federal permit or federal funding requires the federal agency to consult if a listed or proposed species or their critical habitat may be affected within the project action area
  - 9 to 12 months
  - Currently, there is only one listed salmonid in the Chehalis Basin (bull trout) that occurs in the Grays Harbor Estuary and Humptulips River. Several listed wildlife species are also present in the basin. Your local conservation district can help identify if this is an issue at your site.

State Permits and Approvals

- Hydraulic Project Approval
  - Washington Department of Fish and Wildlife
  - Any activity that uses, diverts, obstructs, or changes the natural flow or bed of salt- or freshwaters of the state
  - 3 to 6 months
  - The Washington Department of Fish and Wildlife has 45 calendar days to issue a permit once an application is determined to be complete.
- Clean Water Act Section 401 Water Quality Certification
  - Washington Department of Ecology
  - Any project with a federal permit or federal funding that may result in or create a discharge or runoff or requires excavation in surface waters and jurisdictional wetlands
  - 3 to 12 months
  - Approval is concurrent with a Section 404 or Section 10 permit. Pre-approved for Nationwide Permit No. 13 if conditions are met.

- Coastal Zone Management Act Consistency Determination
  - Washington Department of Ecology
  - Work in the coastal zone (Grays Harbor and vicinity)
  - 3 to 12 months
  - Approval is concurrent with a Section 404 or Section 10 permit.
- Clean Water Act National Pollutant Discharge Elimination System Construction General Stormwater Permit
  - Washington Department of Ecology
  - Any project that will disturb 1 or more acres and have a discharge of stormwater to a state waterbody
  - 2 to 3 months
  - Not required for planting-only projects.
- Aquatic Land Use Authorization
  - Washington Department of Natural Resources
  - Any portion of a project that takes place on state-owned aquatic lands
  - 6 to 12 months
  - Authorization approved after all other permits and approvals are completed.

Local Permits and Approvals

- State Environmental Policy Act Compliance
  - City or county where project is located
  - Any project that requires state or local permits and does not fit within an exemption
  - 2 to 6 months
  - Not required for planting-only projects.
- Shoreline Permit
  - City or county where project is located
  - Projects occurring within the Shoreline Management Zone (within 200 feet of a designated shoreline)
  - 2 to 6 months
  - See following text for more specifics on shoreline requirements for counties within the Chehalis Basin.
- Floodplain Development Permit
  - City or county where project is located
  - Projects occurring within Special Flood Hazard Areas shown on Flood Insurance Rate Maps
  - 2 to 6 months
  - See following text for more specifics.
- Other local permits (clearing, grading, etc.)
  - City or county where a project is located
  - Projects that exceed thresholds for clearing, grading, and fill activities
  - 1 to 3 months
  - Not required for planting-only projects.

The cities and counties within the Chehalis Basin have specific requirements through their Shoreline Master Plans and critical areas codes. For example, the Lewis County Shoreline Master Plan (Lewis County 2021), Grays Harbor County Shoreline Master Plan (Grays Harbor County 2020), and Thurston County Shoreline Master Plan (Thurston County 2023) and critical area codes all encourage applicants to avoid and minimize impacts to ecological functions. As noted previously, emergency actions can be undertaken to protect public safety, health, and the impending loss of a structure, but they should have the least possible impacts to habitats. In addition, mitigation measures will be required to rectify or compensate for impacts in the following dry season. For example, if you take emergency action and install rock, you will likely be required to remove it and restore the bank with a bioengineered solution. Shoreline and bank stabilization projects must consider in the following mitigation sequence:

- Take no action
- Relocate a threatened structure
- Use soft or bioengineering approaches
- Use hard armoring only when no other solutions are possible

Each county and city in the Chehalis Basin have adopted a flood-damage prevention ordinance to comply with the National Flood Insurance Program managed by the Federal Emergency Management Agency. These local ordinances ensure any form of filling, grading, paving, excavation, or other human-created landscape change meets flood safety standards. Each project located in a mapped floodplain or floodway is reviewed under a floodplain development permit process. To determine if your project is in a floodplain or floodway, see the Federal Emergency Management Agency Flood Map Service Center's website (https://msc.fema.gov/portal/home) or your local county website. Erosion control projects proposed to be put in a regulatory floodway must ensure flood elevations will not be impacted.

5. Erosion Management Funding

The Washington Department of Ecology's Office of Chehalis Basin has developed an erosion management program that provides funding for bioengineered projects that benefit willing Basin landowners and minimize impacts to aquatic species habitat.

To receive funding, private or public structures, infrastructure, or agricultural land must be at risk from erosion and meet the following criteria:

- A landowner must partner with a local sponsor such as a conservation district, city or county, or nonprofit entity. The sponsor can provide expertise and help develop and manage the project, including providing financial management and obtaining needed permits.
- The landowner must agree to support a bioengineered solution, allow construction on their property, and maintain the project and any required mitigation over the long term.[3]

Program details are available at: https://chehalisbasinstrategy.com/erosion-management-program/. Project sponsor contacts are listed in **Appendix A.**

Private or public structures and other property eligible for funding from the Erosion Management Program are defined as follows:

- **Public infrastructure:** publicly owned roads, bridges, utilities, schools, park facilities, and other structures.
- **Private residential structures:** homes, barns, or garages, and utilities such as septic systems or water and sewer pipes
- **Commercial structures:** businesses, warehouses, and manufacturing facilities
- **Agricultural land:** privately owned lands actively used for revenue-generating agricultural production

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6. Bioengineering Design Guidance

Erosion management techniques

This section provides an overview of several bioengineering techniques that can be used for erosion management. Bioengineering techniques use natural materials to maintain and improve stream and riparian habitats while slowing erosion.

The techniques listed in this section range from plantings to engineered solutions. They are appropriate for the geomorphic conditions in the Chehalis Basin and can enhance aquatic habitat. Some approaches can be put in place without professional guidance; however, you should consult a professional when measures such as using large wood are being considered; your local conservation district is also a great resource. Remember, larger-scale actions beyond plantings will require a demonstration of the need for bank stabilization in order to obtain permits. **Table 1** provides a summary of several common and suitable bioengineering techniques for the Chehalis Basin. **Appendix C** provides a more comprehensive list of techniques with additional details.

Table 1. Bioengineering techniques for erosion management

Bioengineering technique	Description	Stream size	Resistance to erosion
Erosion control blanket	Biodegradable, open-weave blankets provide temporary cover while establishing vegetation on bare soil areas.	Small stream to medium river	Low
Live stakes	Live woody cuttings are tamped into soil to rapidly root, grow, and stabilize the soil. The technique reinforces and binds soil particles together. Shrub cover slows water velocity.	Small stream to large river	Low to moderate
Woody and herbaceous plantings	Consists of planted or seeded herbaceous and woody vegetation to improve soil and bank stability and provide long-term bank cover.	Small stream to large river	Low to moderate
Brush mattress	Combination of installing live stakes, live bundles, and non-living branch cuttings to cover and protect bare streambanks that grow and establish woody cover.	Small stream to medium river	Low to moderate
Branch packing	Alternate layers of live branches and compacted backfill stabilize and revegetate slumps and holes in streambanks.	Small stream to large river	Low to moderate

Bioengineering technique	Description	Stream size	Resistance to erosion
Willow hedgerows	Dense rows of living willow stakes may have brush layer base to slow velocities and provide bank cover even in areas of land use restrictions.	Small stream to medium river	Low to moderate
Log toe	Logs with root balls attached, anchored in and on streambanks reduce toe scour, slow and deflect flows from the toe of the bank and improve habitat diversity.	Small stream to large river	Low to moderate
Buried wood	Buried large wood, typically root wad logs installed in an excavated trench behind existing bank to slow erosion from future channel migration.	Small stream to large river	Low to moderate
Benching	Reducing a steeply sloping bank by excavating a bench above the ordinary high water line; intended to be used in combination with seeding and planting; may also need fabric or brush mattress protection on exposed soils.	Small stream to large river	Low
Sloping and/or removal of fill	Regrading streambanks to a more stable flatter slope by removing natural or artificially placed bank material can reduce water velocities, allowing flow to spread out further. Use in combination with seeding and planting; may also need fabric or brush mattress protection on exposed soils.	Small stream to large river	Low to high

The techniques are not mutually exclusive. Combining techniques, such as using an erosion control blanket and plantings, will greatly improve the long-term success of a project. Before deciding which techniques to implement, it is important to analyze the project site by following the site assessment guidelines. If the site is in a stable natural condition and no threat exists to existing structures, the site could be monitored first to understand erosion rates before using a specific technique.

If your site assessment indicates upland practices are causing or worsening erosion concerns, you should consider putting best management practices in place before determining an erosion management solution. This can reduce the need for erosion management or help a project function more effectively over time. **Table 2** outlines examples of site best management practices.

Table 2. Site best management practices to reduce erosion

Best management practice	Toe erosion	Local scour	Mass wasting	Bank seepage
Minimize irrigation runoff for lawns and agriculture			X	X
Manage stormwater drainage to reduce surface water flowing down streambanks			X	X
Plant native ground cover instead of manicured grass lawns		X	X	X
Implement swales or buffer strips			X	X
Plant cover crops (e.g., clover)		X	X	X

Erosion control blanket and fabric stabilization

Erosion control blankets and fabrics can be an inexpensive and easy way to manage erosion. The fabric stabilizes exposed sediment. Fabrics are durable and typically made from straw, jute, or coconut fibers (**Figure 9**). The technique is typically paired with plantings, and it helps reduce surface erosion and soil runoff and allows vegetation to grow and stabilize a bank. The costs depends on the material and size of site to be covered.

Materials and equipment needed to install an erosion control blanket include the blankets and stakes. The ground may need to be prepared by removing roots, rocks, or other obstructions and smoothing it prior to placing the blanket.

Figure 9. Erosion control blanket

Vegetation establishment

Establishing vegetation on an eroded bank is relatively inexpensive and simple. Vegetation can also provide multiple benefits to the Chehalis Basin. Trees, shrubs and grasses slow down the rate of erosion and provide cover for the stream and habitat for wildlife. Choose native species to support Basin wildlife. A list of common riparian native plants is provided in **Appendix D** along with a list of non-native invasive weeds that do not stabilize banks or provide any habitat benefits. There are several considerations when using vegetation as the primary stabilization method, including the following:

- Plantings require time to become established so bank protection is not immediate.
- Maintenance will likely be required to replace dead plants or ensure plants become established and self-sustaining.
- Woody plants will only persist when planted above the ordinary high water line. This visual clue will help you establish the ordinary high water line area at or adjacent to your site.
- Plants cannot usually be established when undercutting or toe erosion is happening on the bottom portion of the bank. Plants cannot prevent this type of erosion either.
- Establishing plants in coarse, gravely material may be difficult.

When not using fabric, to retain moisture and reduce weed competition, mulch woody plants with bark mulch or straw following planting.

Live stakes

Available at nurseries or harvested during the dormant season on a landowner's property, live stake trees are intended to take rapid root and grow quickly. Species such as willows and cottonwoods will quickly revegetate a bank (**Figure 10**) and eventually provide soil stability, habitat, and shade. If you are interested in planting your own stakes, take a look at the following resource from Pierce Conservation District: https://piercecd.org/DocumentCenter/View/2030/TAM-27_SFM-Willow-Stakes-how-to.

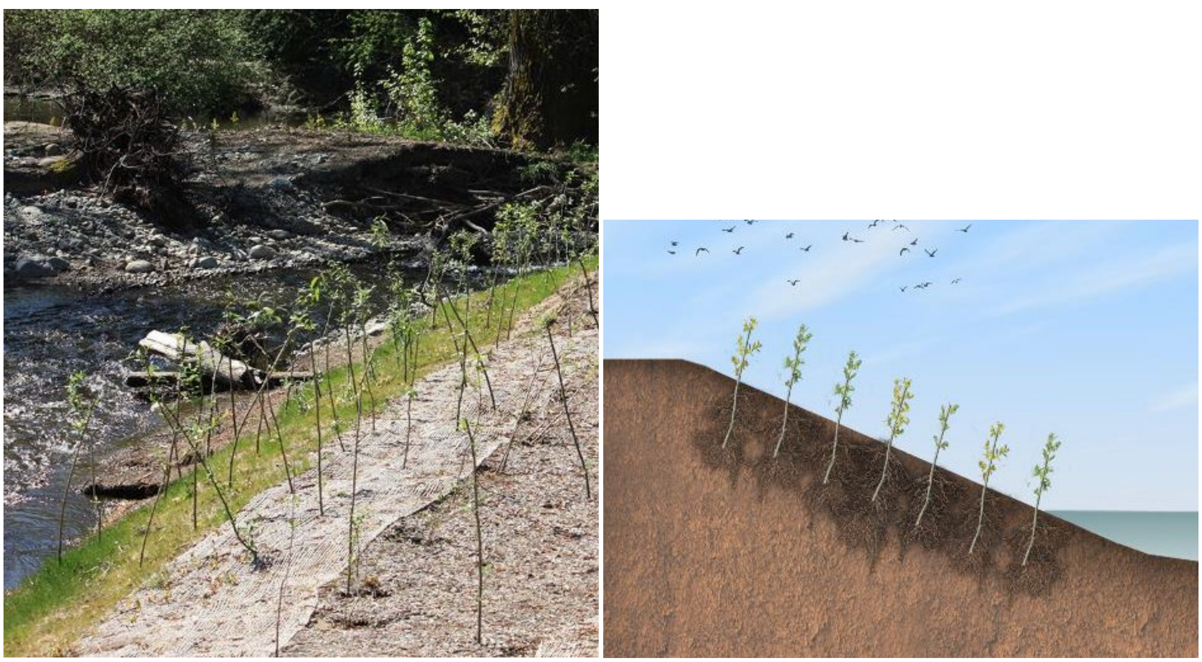

Figure 10. Live stakes photograph and schematic

Woody and herbaceous plantings

In areas where the soil is exposed planting woody and herbaceous vegetation can be an effective option to help control bank erosion. Woody and herbaceous trees and vegetation can help areas where minor degradation has occurred such as small earth slumps, where there is limited existing vegetative cover, and in areas along the bank not located in a high-velocity zone. These plantings help increase a streambank's resistance to erosive forces over time. They also provide shade to help maintain suitable water temperature for fish, provide habitat for wildlife, and contribute to aesthetics.

A list of native plants is provided in **Appendix D**. Plants can be installed from potted stock, bare-root plants, and seedlings. Costs varies based on the types of plants chosen and size of project. The range includes site preparation, plants, and labor.

Brush mattress

A brush mattress is a combination of live stakes, bundles of living and dead branches, and branch cuttings to cover and stabilize banks (**Figure 11**). The mattress forms an immediate protective cover over the bank, and the live stakes and live bundles will grow and provide vegetation cover. Often, brush mattresses are used with additional plantings and a log toe.

Figure 11. Brush mattress

Branch packing

Branch packing is used to repair and restabilize streambanks for small, eroded areas. Branch packing is composed of live stakes, branch bundles, and backfilled soils (**Figure 12**). The technique provides bank stability and, once plants are rooted, provides vegetative root stabilization. A 2024-estimated price to install branch packing, including both labor and materials, is provided in **Appendix E**.

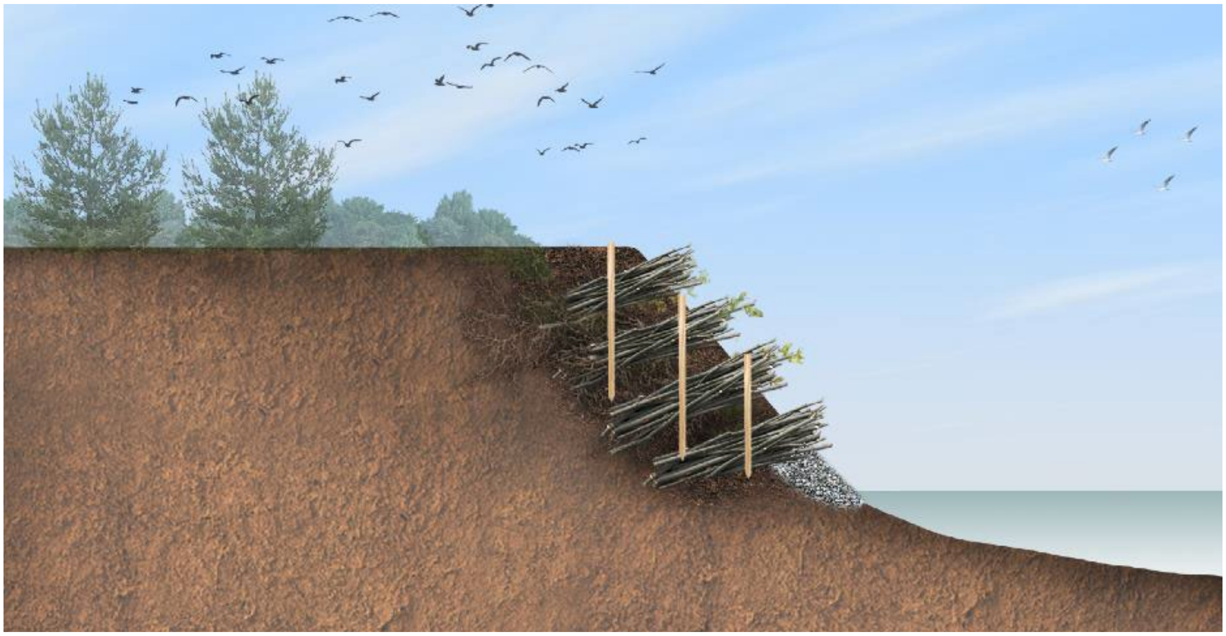

Figure 12. Branch packing

Willow hedgerows

Willow hedgerows are a variation on live staking most suitable along small streams on agricultural land that provide dense rows of willows along the banks (**Figure 13**) and can slow water velocities and stabilize bare soils. They can also provide a barrier to livestock and filter stormwater runoff while maintaining agricultural land uses with minimal reduction in productive lands. Willows can be trimmed to maintain a designated height.

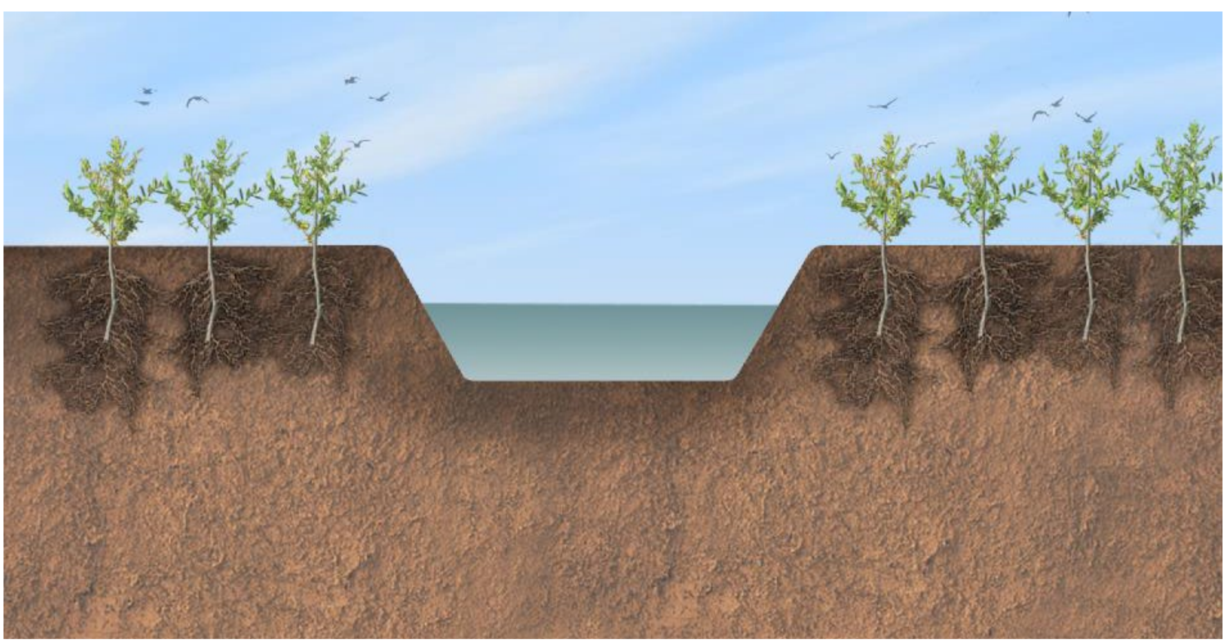

Figure 13. Willow hedgerow

Large woody materials

Using large woody material for restoration projects can achieve a variety of goals. Large woody material slows stream velocities and deflects flow to promote bank stability and form complex aquatic habitats benefitting fish and wildlife.

Log toe

A log toe is a technique that helps resist toe scour by reducing water velocities along the section of the bank that is between the normal water stage and the streambed. Log toes help deflect flows away from the toe scour area. Logs and root balls can also form scour pools that provide cover for fish. Logs are placed at the toe of the slope and may extend up to the ordinary high water line (**Figure 14**). They should be buried or anchored into the bank so they remain in place so plantings can be established. Grading to reduce the slope of the streambank will help the installation of log toes and increase bank stability over time.

Figure 14. Log toe
Logs anchored with piling and erosion control blanket on bare soils. Photograph courtesy Bob Amrine, Lewis Conservation District.

Buried wood

When bank erosion is not causing an immediate threat to structures, buried wood is an option when bank erosion is not causing an immediate threat to structures, and this technique will slow future channel migration. Wood is buried behind an existing bank to form an erosion-resistant hard point (**Figure 15**). Costs associated with buried wood include excavation, labor and equipment, and logs. To reduce opportunities for invasive plant species, it is recommended seeding and planting the disturbed surface after the erosion management project is complete.

Materials and equipment required to install large woody materials include logs (both with rootballs and without), equipment such as excavators to grade trenches and install and lift wood, pile-driving attachment when using piling, and plants, seeding and mulch to cover bare soils.

Figure 15. Buried wood

Bank grading and shaping

Bank grading and shaping is an option for improving bank stability in moderate- to high-risk areas where banks have become too steep. Changing a bank's grade is a commonly used technique along steep or eroding banks undercut and failing due to either toe erosion or mass wasting. It should be coupled with plantings or fabric stabilization to protect the exposed bank from being eroded. Regrading a bank can require equipment, labor, and hauling soils off site.

Photographs and schematics of grading activities can be found in **Figures 16** and **17**.

Benching

Benching is a type of technique used to shape an eroded bank. Benching creates terraces in the streambank that provide erosion control, create habitats, connect floodplains, and offer recreational benefits. For example, benching streambanks can help to reconnect the stream with its floodplain, allowing water to spread out over a wider area during high flow events. This reduces the erosive force of floodwaters and promotes natural processes such as sediment deposition. Benching breaks up a slope into smaller terraces, reducing the force of flowing water and helping distribute it more evenly, preventing concentrated flows that can lead to erosion. A 2024-estimated price to conduct bank benching, including both labor and materials, is provided in **Appendix E**.

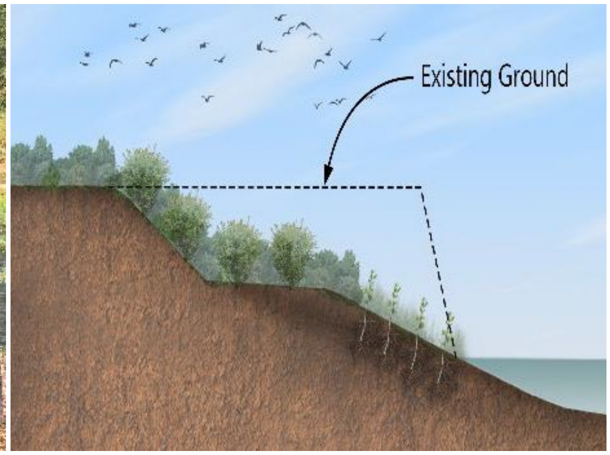

Figure 16. Benching
Freshly excavated floodplain bench adjacent to Skookumchuck River. Photograph courtesy Anchor QEA.

Sloping and fill removal

Removing and grading the upper portion of a streambank can help restore a more stable, less steep slope that can help establish plants along the bank. Removing fill from the bank can expands the width of a river channel and further slow water velocities.

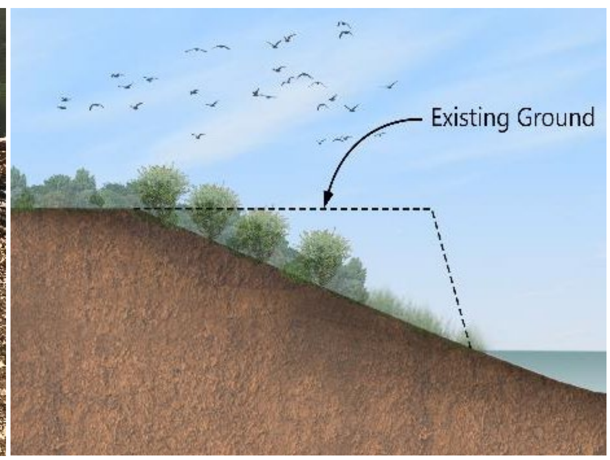

Figure 17. Sloping or removing fill
Freshly excavated and seeded slope adjacent to Skookumchuck River. Photograph courtesy: Anchor QEA.

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Appendix A. Project Sponsor Contacts

Local Conservation Districts

Grays Harbor Conservation District
81 Tower Boulevard
Elma, WA 98541
360-346-7829

Lewis Conservation District
2057 SW Salsbury Avenue
Chehalis, WA 98532
360-996-4560

Thurston Conservation District
582 Tilley Court SE, Suite 152
Tumwater, WA 98501
360-754-3588

Mason Conservation District
450 W Business Park Road
Shelton, WA 98584
360-427-9436

Washington Department of Fish and Wildlife Habitat Biologists
Find the habitat biologist for your location here:
https://wdfw.maps.arcgis.com/apps/MapJournal/index.html?appid=48699252565749d1b7e16b3e34422271

Washington Department of Ecology Office of Chehalis Basin
https://ecology.wa.gov/about-us/who-we-are/our-programs/office-of-chehalis-basin
chehalisbasinstrategy.com

Appendix B. Site Assessment Checklist

Table B-1. Site Assessment Checklist

Number	Characteristic/ activity	Description		Check
1	Location of site	Address.		☐
2	Riparian vegetation	Describe existing vegetation.		☐
3	Bank information	Describe the height, slope and soil type (e.g., clay, gravel) of the bank.		☐
4	Adjacent bank conditions	Describe upstream and downstream bank conditions.		☐
5	Water level fluctuation	Describe the elevation range for typical water level in the stream/river.		☐
6	Type of erosion	Describe type(s) of erosion occurring on the bank (e.g., toe erosion, bank seepage, mass failure, scour).		☐
7	Structural risks	Describe any structures that may be at risk due to shoreline conditions.		☐

Site assessment guidance

This guidance is provided for the Site Assessment Checklist. In general, a site assessment should include the following components:

1. Location
   A. Locate the segment of riverbank that is being assessed.
2. Riparian Vegetation
   A. Describe existing riparian vegetation conditions, including the general location in relation to erosion areas and bank slopes.
   B. Identify the types of existing vegetation (e.g., trees, shrubs, grasses, or invasive species) and relative size or age of trees.
   C. Identify areas where riparian vegetation has been removed.
3. Bank Information
   A. Determine if the riverbank is steep or gentle.
      i. A steep bank has a vertical rise-to-horizontal run ratio of 1:1 or less.
   B. Document any major changes in the slope and soil type and location relative to the typical water level.
   C. Document riverbank conditions upstream and downstream from the proposed project.
   D. Consider how the proposed bank stabilization measures will fit into or impact the adjacent riverbank. A comprehensive stabilization project that incorporates work on adjacent banks and works with natural processes is typically more successful than those constrained by property boundaries. For example, working with neighbors to work with a larger river process, such as a long migrating river bend, can be more effective than working on an individual site.
4. Adjacent Property Bank Conditions
   A. Identify conditions on adjacent properties, such as level of existing vegetation, slopes, evidence of erosion, and existing improvements.
5. Water Level Fluctuations
   A. Determine the range of water levels that can be expected at the project site.
   B. The placement of woody material, vegetation, and earthwork depends on water levels.
6. Type of Erosion
   A. See Section 2 of this Erosion Management Guidebook for examples of mechanisms of failure.
7. Structural Risks
   A. Describe any structures that may be at risk due to bank conditions.

Appendix C. Comprehensive List Of Bioengineering Techniques

Table C-1. Potential Chehalis Basin bioengineering techniques

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
Fabric stabilization	Coir (coconut husk) logs	Cylindrical structures that may be composed of coconut husk fibers bound together with twine woven from coconut material to protect slopes from erosion while trapping sediment, which encourages plant growth within the fiber roll.	Small stream to large river	Low to moderate	Scour, seepage	• Forms an immediate protective cover over the streambank • Captures sediment during flood flows • Provides opportunities for rooting of the cuttings over the streambank • Rapidly restores riparian vegetation and streamside habitat • Enhances conditions for colonization of native vegetation • Appropriate where exposed streambanks are threatened by high flows prior to vegetation establishment • Composed of biodegradable materials only	• Not applicable as a stand-alone technique for high-velocity sites unless used in combination with structural toe protection placed below the coir logs • Not appropriate where scour and undercutting can undermine the coir logs • Not particularly effective for large sites • Limited to the slope above base flow levels • Should not be used on slopes that are experiencing mass movement or other types of slope instability • Irrigation is often necessary in mid to upper banks of drier site • Creates a smooth bank line providing limited roughness
	Fabric encapsulated lifts	Bioengineered bank stabilization consisting of constructed lifts of fabric wrapped soils, interlaced with rooted willow plants.	Small stream to large river	Low to moderate	Toe erosion, scour, seepage	• Allows establishment of vegetation that will slow erosion but not completely harden the bank • Composed of biodegradable materials only	• Only lasts 3 to 5 years and relies on plant establishment
	Erosion control blanket	Biodegradable, open-weave blankets provide temporary cover and support for establishing vegetation on bare soil areas.	Small stream to medium river	Low	Toe erosion, scour, seepage	• Excellent for mitigating surface erosion • The blanket offers immediate and uniform slope protection from rain and overland water flow if it is installed in full contact with the soil surface • Composed of biodegradable materials only	• Can be labor intensive and may require more investment to install • Requires numerous wood stakes or live stems to secure the blanket • Too much grass seeded on the blanket can lead to overcompetition for moisture, sunlight, and nutrients and may result in high tree and shrub mortality
Live plantings	Brush mattress	Combination of live stakes, live fascines, and branch cuttings to cover and physically protect streambanks; eventually sprouts and establishes numerous individual plants.	Small stream to medium river	Low to moderate	Toe erosion, bank erosion, meander migration	• Forms an immediate protective cover on slopes • Captures sediment during rainfall events and flood flows • Protects cuttings while they root and grow • Rapidly restores riparian vegetation and streamside habitat • Enhances conditions for colonization of other native vegetation	• Limited to the slope above base flow levels

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Live stakes	Live woody cuttings that are tamped into the soil to root, grow, and create a living root mat that stabilizes the soil by reinforcing and binding soil particles together; can provide rapid cover.	Small stream to large river	Low to moderate	Mass wasting, meander migration	• Quickly and inexpensively establishes riparian vegetation • Applicable at low or high bank sites • Appropriate for repair of small earth slips and slumps that are frequently wet • Can be used to stake down surface erosion control materials • Enhances conditions for colonization of other native vegetation	• Requires toe protection where toe scour is anticipated • Only effective where the water table is high enough for cuttings to reach it • Not effective on its own where rapid erosion and scour is occurring
	Joint plantings	Live stakes tamped into joints or openings between rock that have previously been installed on a slope or while rock is being placed on the slope face.	Creek to large river	Low to moderate	Meander migration	• Appropriate where there is a lack of desired vegetative cover on the face of existing or required rock riprap • Root systems provide a mat upon which the rock riprap rests and prevents loss of fines from the underlying soil base • Root systems also improve drainage in the soil base • Will quickly establish riparian vegetation • Can be installed from base flow levels to top of slope if live stakes are installed to reach groundwater	• Not always applicable as a stand-alone technique for high-velocity sites unless used in combination with a toe protection technique • Thick rock riprap layers may require special tools for establishing pilot holes • Survival rates can be low due to damage to the cambium or lack of soil/stake interface
	Live fascines	Dormant branch cuttings bound together into long, sausage-like, cylindrical bundles and placed in shallow trenches on slopes to reduce erosion and shallow sliding.	Small stream to medium river	Low to moderate	Bank erosion, meander migration	• Effective stabilization technique for streambanks, requiring a minimum amount of site disturbance • Applicable at low or high bank sites • Can trap and hold soil on streambank by creating small dam-like structures and reducing the slope length into a series of shorter slopes • Facilitates drainage when installed at an angle on the slope • Enhances conditions for colonization of native vegetation	• Requires toe protection where toe scour is anticipated • Not appropriate for treatment of slopes undergoing mass movement • Not always applicable as a stand-alone technique for high-velocity sites unless used in combination with a toe protection technique
	Brush layering/ branch packing	Alternate layers of live branches and compacted backfill, which stabilize and revegetate slumps and holes in streambanks.	Small stream to large river	Low to moderate	Toe erosion, meander migration	• Beneficial where streambank has already scoured out • Enhances plant colonization • Provides soil reinforcement	• Not effective in larger slump areas (greater than 4 by 4 feet)

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Rooted stocks	Any tree, woody shrub, or herbaceous plant with established roots, including rooted cuttings, balled and burlapped, bare-root, and containerized plants. Used either alone or with other methods to provide leafy cover and root strength; sends roots into the surrounding soil in weeks, faster than cuttings that may take months. May be placed anywhere on the bank where it will not be removed by erosive flows.	Small stream to large river	Low to moderate	Bank scour, meander migration	• May be used for planting during the growing season when unrooted cuttings may not survive • Useful where soils are droughty, nutrient poor, where rooting of cuttings is doubtful, or when cuttings of desired species are unavailable • May be added where understory vegetation already exists and larger shade-providing plants are desired • Rooted stock provides immediate vegetative cover and habitat improvement • Depending on the root distribution needed, plants may be spread evenly across the site for uniform cover or clumped for a more natural appearance (the plants vary in size from small [few inches] to large [10 or 12 feet tall])	• Containerized stock has a relatively high cost per plant • Even with established roots, rooted stock at some sites may require irrigation for one or more seasons
	Herbaceous cover	Consists of planted or seeded herbaceous vegetation used to improve soil and bank stability and provide rapid cover for wildlife habitat and site aesthetics. Herbaceous vegetation consists of grass and grass-like wetland plants and includes rushes, sedges, ferns, legumes, forbs and wildflowers. In contrast to woody vegetation, herbaceous vegetation tends to have roots that are shallow, fine, and dense and form a more continuous mat across the soil surface.	Small stream to large river	Low to moderate	Bank scour, meander migration	• If used in combination with other bank protection and erosion control techniques, such as toe protection and/or erosion control fabric, herbaceous cover can provide immediate protection against surface erosion • Applicable as a stand-alone treatment on a streambank that has a relatively stable toe but has poor vegetative cover and possibly some surficial erosion or modest, reach-based aggradation • May also be an excellent choice as ground cover in parks and urban areas where flood conveyance and ease of maintenance is important	• Not always applicable for sites where undercutting or mass failure occurs unless used in combination with a toe protection technique • Cannot be used as the primary method to control major bank erosion problems • Due to the relatively shallow rooting depths of grasses, this treatment should not be used on reaches where degradation and channel downcutting is widespread • Does not provide significant shade or cover to the stream, thus only minimally improving fish habitat

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Willow fencing	Short fence or wall built of living cuttings that may have a brush layer base intended to slow and redirect floodwaters away from a bank or floodplain area.	Small stream to medium river	Low to moderate	Bank scour, meander migration	• These structures reduce slope angle, providing a stable platform for vegetation to establish • Willow fences trap rolling rocks and sliding debris and protect vegetation growing lower on the slope • Willow fences provide support for small shallow translational or rotational failures • When the structure begins to decay, root systems of other plants will serve as the permanent feature • Most suitable in areas with high water table for willow/brush layering fence installations • Can be constructed on dryer sites, but it is important to establish deeper rooting shrubs and trees within the shelf	• Significant quantity of plant material is required • Moist site conditions are required for the fence to sprout and grow
Large woody material	Live crib	Hollow, box-like interlocking arrangements of untreated log or timber members with or without root wads that are filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.	Small stream to large river	Low to high	Toe erosion, seepage, mass wasting, meander migration	• Effective in high-velocity areas • Appropriate both above and below the water where the channel is not incising • Provides protection to the streambank in areas with near vertical banks where bank sloping options are limited • Affords a natural appearance, immediate protection, and accelerates the establishment of woody species • Effective on outside of bends of streams where high velocities are present • Appropriate at the base of a slope where a low wall might be required to stabilize the toe and reduce slope steepness	• May require higher level of investment to install • Structure may have only limited ability to adjust to toe scour • Should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation • Site must be accessible to heavy equipment • Materials might not be readily available at some locations

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Log toe	Boulders and logs with root masses attached that are placed in and on streambanks to provide streambank erosion, trap sediment, and improve habitat diversity.	Small stream to large river	Low to medium	Toe erosion, bank scour, degrading reach	• Can be anchored with boulders or piling or wedged through existing trees • Will tolerate high boundary shear stress if logs and root wads are well anchored • Suited to streams where fish habitat deficiencies exist • Will enhance diversity in riparian areas when used with soil bioengineering systems • Might need eventual replacement if colonization does not take place or soil bioengineering systems are not used • Use of native materials can sequester sediment and woody debris, restore streambanks in high-velocity streams, and improve fish rearing and spawning habitat	• Should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation • Will have limited life depending on climate and tree species used; some species, such as cottonwood or willow, often sprout and accelerate colonization • Site must be accessible to heavy equipment • Materials might not be readily available at some locations • Can create local scour and erosion • May require higher level of investment to install
	Large wood deflector (i.e., bank barb)	Wood structures that protrude from either streambank, but do not extend entirely across a channel, to deflect flows away from the bank and scour pools by constricting the channel and accelerating flow.	Creek to large river	Low to high	Toe erosion, bank scour	• Can tolerate high boundary shear stress • Should be installed in series on the same streambank to push the thalweg away from the bank or on alternating streambanks to produce a meandering thalweg and associated structural diversity • Should be designed and located far enough downstream from riffle areas to avoid backwater effects that would drown out or otherwise damage the riffle • Must be sized on anticipated scour • The material washed out of scour holes is usually deposited a short distance downstream to form a bar or riffle area; these areas of deposition are often composed of clean gravels that provide excellent habitat for certain species • Should be used in channels with low physical habitat diversity, particularly those that lack stable pool habitat	• Should be combined with vegetative plantings to stabilize upper banks/slopes • May require higher level of investment to install • Deflectors placed in sand bed streams may settle or fail due to erosion of sand, and in areas a filter layer or geotextile might be needed underneath the deflector • Site must be accessible to heavy equipment • Materials might not be readily available at some locations • Response can be unpredictable, creating undesired local scour and erosion

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Engineered log jam	Structures composed of large woody material installed in the channel to redirect flows.	Creek to large river	Low to high	Toe erosion, bank scour, degrading channel, meander migration	• Can tolerate high boundary shear stress if well anchored • Can be anchored with boulders, piling, or wedged through existing trees • Will tolerate high boundary shear stress if logs and root wads are well anchored • Suited to streams where fish habitat deficiencies exist • Use of native materials can sequester sediment and woody debris, restore streambanks in high-velocity streams, and improve fish rearing and spawning habitat	• Site must be accessible to heavy equipment • Materials might not be readily available at some locations • Response can be unpredictable, creating undesired local scour and erosion • May requirement higher level of investment to install
	Buried wood setback	Buried large woody materials, typically root wad logs installed on the floodplain in an excavated trench; typically installed down to the elevation of the river bottom to create a limit for future channel migration.	Creek to large river	Low to medium	Bank scour, meander migration	• Does not require working in the channel and has minimal environmental impacts	• Site must be accessible to heavy equipment • May require higher level of investment to install • Will only be effective once erosion and channel migration has occurred
	Floodplain roughness	Placing or partially burying woody materials to increase roughness and reduce velocities on the floodplain.	Creek to large river	Low to medium	Mass wasting, bank scour, meander migration	• Relatively low cost • Can be constructed using on-site materials	• Woody material is more prone to degrade and wash away • Not as effective in high-energy environments • Does not address toe erosion
	Floodplain fencing	Combination of timber piling and other woody materials buried into the floodplain to limit meander migration and accumulate additional woody material as bank erosion occurs.	Creek to large river	Low to high	Bank scour, meander migration	• Helps recruit additional large wood, creating a more natural feature • Effective in a range of energy environments	• Site must be accessible to heavy equipment and have room for excavation and installation
	Tree revetment	A pervious line of wood materials, made from whole trees cabled together and held in place with rock and anchors buried in the bank.	Creek to large river	Low to medium	Toe erosion, bank scour, meander migration	• Relatively inexpensive, semipermanent form of protection • Slows and deflects high bank velocities; limits toe erosion • As it collects sediment and begins to revegetate, it becomes more natural in appearance and function • Can provide cover for aquatic species	• Cables and other anchor materials are seen as non-natural and may not be desired • Have a limited life and must be replaced periodically; loss of trees through damage or deterioration will expose the bank to the current; if revetment is not repaired, bank will continue to undercut and erode

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Log terracing	Uses alternating terraced logs to stop surface erosion on eroding slopes, which is critical for successful revegetation efforts; specifically, log terracing shortens slope length and gradient between each structure, providing stable planting areas throughout most of the slope face.	Creek to large river	Low	Bank scour, seepage	• Logs create terraces reducing length and steepness of slope, provides stable areas for establishment of other vegetation such as trees and shrubs	• Labor intensive and with potential safety hazards on steep slopes
Grading activities	Bank shaping	Regrading streambanks to a stable slope; placing topsoil and other materials needed for sustaining plant growth; and selecting, installing, and establishing appropriate plant species.	Small stream to large river	Low	Toe erosion, mass wasting, aggrading reach, meander migration	• Applicable at low or high bank sites • Successful on streambanks where moderate erosion and channel migration are anticipated • Enhances conditions for colonization of native species • Streambank soil materials, probable groundwater fluctuation, and bank loading conditions are factors for determining appropriate slope conditions	• Additional toe reinforcement may be necessary • Must be used in conjunction with other protective practices if flow velocities exceed the tolerance range for available plants, and where erosion occurs below base flows
	Benching	Excavating a floodplain bench into a steep eroding bank, typically done to an elevation at or just above the ordinary high water line, with the intent of spreading floodwaters to reduce local velocities and allow riparian vegetation to re-establish.	Small stream to large river	Low to medium	Bank scour, mass wasting	• Inexpensive approach • Will help establish riparian vegetation by lowering bank elevations	• Additional toe reinforcement may be necessary • Will not halt channel migration unless vegetation can establish • High velocities may prevent vegetation establishment
	Reconnection of side channel	Excavating to promote flow (or more flow) into an existing or constructed side channel to reduce energy acting on an adjacent eroding bank.	Small to large river	Low to high	Toe erosion, bank scour, meander migration	• Promotes natural processes • May not require any additional bank stabilization measures	• Site must be accessible to heavy equipment • Can be higher in cost if extensive channel excavation is required • Only suitable for locations with existing channels or swales or low floodplain
	Gravel bar chute	Excavating one or more channels through an adjacent gravel bar (e.g., on opposite bank) to reduce energy acting on an eroding bank.	Small stream to large river	Low to high	Toe erosion, bank scour, meander migration	• Cheap and relatively simple approach • May not require any additional bank stabilization measures	• Requires access and permission to adjust adjacent gravel bar • May only reduce energy over the short term (1 to 5 years) • Site must be accessible to heavy equipment • Should be used in combination with revegetation or other techniques that will provide long-term stabilization

Treatment category	Technique	Description	Stream scale	Energy environment	Bank issue addresses	Advantages	Disadvantages
	Removal of fill	Removing fill or regraded areas in the channel or floodplain to create more room for the river and promote natural stream processes.	Small stream to large river	Low to high	Bank scour, meander migration	• Removes confining fill or hillslopes that are causing high velocities and erosion • May not require any additional bank stabilization measures	• Site must be accessible to heavy equipment • Need a disposal site for these materials
	Gravel augmentation	Importing and dumping gravel upstream of a sediment supply-limited reach to encourage deposition downstream and reduce stream power.	Small stream to large river	Low to high	Degrading reach	• Promotes natural processes and channel equilibrium • May not require any additional bank stabilization measures	• May have higher life-cycle costs if it needs to be repeated • More of a reach-scale approach; may not help a localized site • Site must be accessible to heavy equipment

Appendix D. Plant Lists

Table D-1. Suggested native riparian species for planting in the Chehalis Basin

Scientific name	Common name	Type	Notes
Acer circinatum	Vine maple	Shrub	Fast growing; plant in wetter areas
Acer macrophyllum	Big-leaf maple	Tree	Slow growing; plant in drier, sunnier areas
Alnus rubra	Red alder	Tree	Fast growing; grows in most soils
Berberis aquifolium	Tall Oregon grape	Shrub	Moderate growing; plant in drier, sunnier areas
Cornus stolonifera	Red osier dogwood	Shrub	Fast growing; plant above willow zone
Frangula purshiana	Cascara	Shrub	Moderate growing; plant in shady areas
Physocarpus capitatus	Nine-bark	Shrub	Moderate growing; plant above willow zone
Picea sitchensis	Sitka spruce	Tree	Moderate growing; most appropriate in lower elevation
Polystichum munitum	Sword fern	Fern/ Herbaceous	Fast growing; plant in shady areas for ground cover
Populus balsamifera	Black cottonwood	Tree	Fast growing; can be planted as live stake or potted stock
Pseudotsuga menziesii	Douglas fir	Tree	Fast growing; plant in drier, sunnier areas
Rosa nutkana	Nootka rose	Shrub	Fast growing; plant in sunny areas
Rosa pisocarpa	Cluster flowered rose	Shrub	Fast growing; plant in wet areas
Rubus nutkanus	Thimbleberry	Shrub	Moderate growing; plant in drier areas
Rubus spectabilis	Salmonberry	Shrub	Fast growing; plant in wet areas
Salix lucida	Pacific willow	Shrub	Fast growing; tallest willow; plant in wet areas; live stakes primary
Salix scouleriana	Scouler willow	Shrub	Fast growing; plant in wet areas; live stakes primary
Salix sitchensis	Sitka willow	Shrub	Fast growing; plant in wet areas; live stakes primary
Symphoricarpos albus	Snowberry	Shrub	Moderate growing; plant in drier areas
Thuja plicata	Western red cedar	Tree	Mix with spruce
Tsuga heterophylla	Western hemlock	Tree	Moderate growing; will grow in sun

Non-native invasive weeds

Non-native invasive weeds are non-native plants that have been introduced to Washington from other parts of the world. They typically have very aggressive growth rates and few natural predators or diseases. These species can be damaging, competitive, or difficult to control. These species degrade native plant and animal habitat, damage recreational opportunities, lower land values, and create erosion problems and fire hazards, and some species can even poison humans and livestock.

Washington State and all counties within the Chehalis Basin have noxious weed lists and resources, including the Noxious Weed Control Boards, which can be accessed via the state Noxious Weed Control Board website (https://www.nwcb.wa.gov/grays-harbor-county-noxious-weed-control-board).

Table D-2 lists non-native invasive weed species that are commonly found in riparian zones and floodplains of the Chehalis Basin. These species are all classified as Category C weeds that are typically widespread throughout Washington but may be of special interest to the agricultural industry. Class C weeds may be designated by a county weed board for required control or they may instead be subject to technical assistance and education to support landowners in control.

Table D-2. Commonly observed non-native invasive weeds in riparian zones and floodplains in the Chehalis Basin

Scientific name	Common name	Type	Notes
Cirsium arvense	Canada thistle	Perennial herb	Can be controlled with manual removal and herbicide treatment
Cirsium vulgare	Bull thistle	Perennial herb	Can be controlled with manual removal and herbicide treatment
Conium maculatum	Poison hemlock	Perennial herb	Poisonous to humans and livestock; control with cutting and herbicide
Crataegus monogyna	English hawthorn	Shrub	Can be controlled with cutting and herbicide treatment
Cytisus scoparius	Scot's broom	Shrub	Can be controlled with cutting and herbicide treatment
Dipsacus fullonum	Teasel	Perennial herb	Can be controlled with manual removal and herbicide treatment
Fallopia x *bohemica*	Bohemian knotweed	Perennial herb	Highly invasive, can be controlled with cutting and herbicide treatment
Fallopia japonica	Japanese knotweed	Perennial herb	Highly invasive, can be controlled with cutting and herbicide treatment

Scientific name	Common name	Type	Notes
Fallopia sachalinense	Giant knotweed	Perennial herb	Highly invasive, can be controlled with cutting and herbicide treatment
Hedera helix	English ivy	Woody groundcover	Can be controlled by goats, manual removal, and herbicide treatment
Ilex aquifolium	Holly	Shrub	Can be controlled with cutting and herbicide treatment
Iris pseudacorus	Yellow-flag iris	Perennial herb	Can be controlled by digging up bulbs and herbicide treatment
Jacobaea vulgaris	Tansy ragwort	Perennial herb	Can be controlled with manual removal and herbicide treatment
Lythrum salicaria	Purple loosestrife	Perennial herb	Highly invasive, can be controlled with digging and herbicide treatment
Phalaris arundinacea	Reed canary grass	Perennial grass	Highly invasive, difficult to control, can use mowing and herbicide treatment or mowing and covering with cardboard, fabrics, or other materials
Rubus armeniacus	Armenian blackberry	Shrub	Can be controlled with cutting and herbicide treatment
Rubus laciniatus	Evergreen blackberry	Shrub	Can be controlled with cutting and herbicide treatment
Sonchus arvensis	Field milk thistle	Annual herb	Can be controlled with manual removal and herbicide treatment

Appendix E. Costs For Bioengineering Techniques

Table E-1. Materials, methods, and costs for bioengineering techniques

Bioengineering technique	**Common materials and methods**	**Average costs ($)***	
		Materials	**Installation****
Erosion control blanket	• Coir blankets • Wooden stakes • Ground preparation and removal of roots, rocks, etc.	$1 per square foot	$1 per square foot
Live staking	• Live stakes (willows or dogwood) • Bark mulch or straw to retain moisture and reduce weed competition • Small hand tools such as shovels and augers for installation	$300 to $500 per 100 linear feet of bank line	$300 to $500 per 100 linear feet of bank line
Woody and herbaceous plantings	• Potted plants, bare-root plants, and/or seeds • Bark mulch or straw to retain moisture and reduce weed competition • Small hand tools such as shovels and augers for installation	$2,000 to $10,000 per acre	$2,000 to $10,000 per acre
Brush layering/ branch packing	• Live stakes (willows or dogwood) • Branches from native trees • Jute rope for bundling • Wooden stakes • Plants/seeding • Mulch to cover bare soil • Small machinery to excavate trenches	$200 to $300 per 100 linear feet of bank line	$100 to $300 per 100 linear feet of bank line
Willow hedgerows	• Willow plantings • Mulch to cover bare soil • Excavator	$200 to $300 per 100 linear feet of bank line	$100 to $300 per 100 linear feet of bank line

Bioengineering technique	Common materials and methods	Average costs ($)*	
		Materials	**Installation****
Log toe	• Logs (both with rootballs and without) • Plants/seeding • Live stakes (willows or dogwood) • Mulch to cover bare soils • Heavy equipment (such as excavators and logging machinery) to grade trenches and install/lift wood • Excavator with pile-driving capabilities and attachment (when installing log piling)	$20,000 to $50,000 per 100 linear feet of bank line***	$20,000 to $40,000 per 100 linear feet of bank line***
Buried wood	• Logs (both with rootballs and without) • Plants/seeding • Mulch to cover bare soils • Heavy equipment (such as excavators and logging machinery) to grade trenches and install/lift wood • Equipment with pile-driving capabilities and attachment (when installing log piling)	$10,000 to $20,000 per 100 linear feet of bank line***	$5,000 to $20,000 per 100 linear feet of bank line***
Benching	• Plants/seeding • Mulch to cover bare soils • Heavy equipment (such as excavators) to excavate and regrade floodplain	$3,000 to $5,000 per 100 linear feet of bank line****	$2,000 to $5,000 per 100 linear feet of bank line****
Sloping and/or removal of fill	• Plants/seeding • Mulch to cover bare soils • Heavy equipment (such as excavators) to excavate and regrade floodplain	$3,000 to $5,000 per 100 linear feet of bank line****	$2,000 to $5,000 per 100 linear feet of bank line****

Notes:
* Costs are in 2024 dollars.
** Costs include labor and equipment for a contractor to complete the work.
*** Range is dependent on number of layers in structure, cost variability, and whether pile driving is required to complete the work.
**** Range is dependent on existing bank height, volume of material removed, and other cost variables.