# Appendix L
## Cost of Techniques

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# Appendix L
## Cost of Techniques

*Ultimately, the Aquatic Habitat Guidelines program intends to offer one complete set of appendices that apply to all guidelines in the series. Until then, readers should be aware that the appendices in this guideline may be revised and expanded over time.*

Cost is often included as criteria for design and may influence selection of a treatment or dictate what protection techniques may be considered as alternatives. Bank-protection costs include design, materials, construction and dewatering, revegetation, monitoring, maintenance, mitigation and permitting. Design costs are typically 10 to 20 percent of construction costs, including revegetation. Monitoring, maintenance and permitting costs vary widely among project types and specific regulatory requirements.

Costs for bank protection are highly variable and can range from a few dollars to hundreds of dollars per foot of bank protected, depending upon the project site, design criteria and scale of the project. Cost is also highly site-dependent. Site-dependent variables include materials availability and hauling cost, dewatering methods, site and construction access, utilities, mitigation requirements and irrigation.

In addition to the direct costs of bank protection, costs associated with the following items should be considered in order to estimate the full cost of a bank-protection action (these are discussed in more detail in the *Risk Assessment* section of Chapter 4, *Considerations for a Solution*):

- repair of damage to property and infrastructure;
- relocation of at-risk facilities;
- compliance with habitat-protection requirements under the federal Endangered Species Act or other laws;
- restoration of the channel to prevent further habitat losses caused by the protection action; and/or
- habitat mitigation for the duration of the project's impact, including monitoring and adjustments.

Mitigation requirements often include specific limitations on project timing, access, type of equipment allowed and damage to the natural streambank, all of which will affect project cost.

## COST ESTIMATING

This appendix is intended to provide generalized information about bank-protection costs. Site-specific, project-specific criteria, as well as permitting requirements impact total bank-protection costs more than the streambank-protection technique selected. The cost examples provided here are derived from projects conducted in Washington State in recent years; however, due to the variability of site- and project-specific influences, these examples may have only limited applicability to any other site.

Cost estimates for bank protection can be derived as follows:

1. *Design streambank protection.* At a minimum, costs of a streambank-protection project cannot be effectively estimated without a conceptual design. With conceptual design, cost can be estimated based on cost of similarly constructed projects with similar implementation components and characteristics (access, tie-backs, dewatering). Generally speaking, a conceptual design usually represents about 30 percent of the final design.
2. *Estimate of materials cost.* Calculate quantities of all materials necessary for construction, and research unit prices for these materials. Unit prices may vary according to volume. Determination of unit prices should always be based on information from suppliers and should account for transportation expenses to and from the site.
3. *Determine construction sequence.* Development of the construction sequence determines many important construction-cost considerations such as what equipment is required, where access roads are needed, where staging areas can be set up and whether dewatering will be necessary. Contractors can be very helpful in determining construction sequencing and in providing cost estimates but often will need substantially more than conceptual drawings to provide estimates.
4. *Calculate cost of mitigation, monitoring and maintenance.* Maintenance costs can conservatively be estimated as five to 10 percent of construction costs; although, in riparian-restoration projects, costs may be significantly higher. Mitigation and monitoring costs will be project-specific, depending upon mitigation requirements and monitoring objectives.

## Design Cost

The cost of design for streambank-protection projects is typically 10 to 15 percent of construction costs, including contingencies. Design cost depends largely upon level of analysis and format of designs. Plans may be sufficiently detailed to allow the project to be let to bid on a lump-sum basis, or largely conceptual in nature and intended only to provide guidance. For example, on a bank-reshaping project that does not require a constructed toe or dewatering, construction may proceed with little design and may be as little as five percent of total cost, depending upon permitting requirements. Conversely, on a soil-reinforced project that requires detailed drawings to contract for the project and to meet permitting requirements, design costs may approach 15 percent of total cost. Sedimentation and erosion-controls plans often require an additional level of detail. Furthermore, the nature of dewatering methods used may add considerably to design costs. The level of detail required may be a function of permitting requirements.

## Materials Costs

The following categories describe materials incorporated into streambank-protection projects:

- *rock materials* - for bank-toe, upper-bank construction or filter drains;
- *soil materials* - for backfill or topsoil;
- *fabrics* - for reinforcement or erosion control;
- *artificial materials* - for fabricated structural or internal geotechnical components;
- *plant materials* - for revegetation; and
- *wood materials* - for habitat components and bank-toe or upper-bank construction.

Typical costs for specific materials in each of these categories are listed in *Table L-1*. It's important to note that these are installed costs, which include purchase of the material, hauling to the site, excavation, spoilage and installation.

| Material Type | Unit of Measure | Unit Cost |
|---|---|---|
| ***Rock Materials*** | | |
| Riprap | Cubic Yard | $60-$80 |
| Pit Run | Cubic Yard | $30-$40 |
| River Gravel | Cubic Yard | $40-$80 |
| River Cobble | Cubic Yard | $80-$100 |
| Boulders (2-4 ft diameter) | Cubic Yard | $40-$60 |
| Filter Gravel | Cubic Yard | $40-$60 (placed) |
| ***Soil Materials*** | | |
| Topsoil (standard grade) | Cubic Yard | $10-$15 |
| Structural Fill | Cubic Yard | $60-$80, includes compaction |
| ***Fabric Materials*** | | |
| Woven Coir Fabric | Square Yard | $2.00-$3.00 |
| Nonwoven Coir | Square Yard | $1.00-$2.00 |
| Nonwoven Geosynthetic Filter Fabric | Square Yard | $0.50-$0.68 |
| Biodegradable Geotextile Fabric | Square Yard | $2.85-$3.00 |
| ***Artificial Materials*** | | |
| Doloes | Each | $200-$900 |
| ***Plant Materials (see Table L-3)*** | | |
| ***Wood Materials*** | | |
| Large Wood With Rootwad | Each | $500-$750 |
| Large Wood Without Rootwad | Each | $200-$300 |
| **MISCELLANEOUS** | | |
| Wooden Stakes | Each | $0.40 - $0.75 |
| Cable | Linear Foot | $0.75 (1/2" diameter) |
| Cable Clamps | Each | $0.54 (cost varies based on cable diameter) |

*Table L-1. Typical costs of streambank-protection materials.*

The cost of nonmanufactured materials, such as soil, rock and large woody debris is greatly affected by transportation and installation costs. Transportation generally requires loading the materials into street-legal vehicles, hauling, stockpiling and distributing within a project site. Materials costs can be reduced by finding on-site sources of rock and soil that can be excavated and installed with a single piece of equipment, such as a loader or dozer. However, this will depend to a great degree upon permit conditions and mitigation requirements and is generally problematic on sites where vegetation and site disturbance should be kept to a minimum.

## Construction and Dewatering Costs

Construction costs include mobilization, installation (and eventual removal) of access and haul roads, dewatering, sediment control and bank-treatment construction. Construction costs are site-dependent and tend to increase dramatically with restrictions on site access and project scope. For example, a bank-protection project within a small and confined urban stream may limit equipment size and construction operations, reducing progress rates and increasing costs. Conversely, an easily accessed rural project on a larger river may accommodate large equipment and stockpile areas and may also provide an on-site source for some materials, thereby improving progress rates substantially.

For further discussion of access and haul roads, equipment selection and dewatering, refer to Appendix M, *Construction Considerations*.

| Construction/Dewatering Components | Unit of Measure | Unit Cost |
|---|---|---|
| ***Access and Haul Roads*** | | |
| Access with Geotextile Base | Linear Foot | $10-$20 |
| ***Dewatering*** | | |
| Portadam Coffer Dam (dry) | Linear Foot | $25-$40 |
| Cement Barrier (wet) | Linear Foot | $10-$25 |
| Gravel Barrier | Linear Foot | $5-$25 |
| ***Sediment Control*** | | |
| Silt Fence | Linear Foot | $1.50-$2.50 |
| Straw/Hay Bale Barrier | Linear Foot | $1-$3 |

*Table L-2. Range of costs for construction and dewatering components of bank-protection projects in the state of Washington.*

## Revegetation and Planting Costs

Revegetation is an integral part of any bank-protection project, or an associated component of repairing construction-related disturbance. Revegetation materials include seed, cuttings and plants that are rooted, balled, burlapped or potted. Mulch and irrigation are also considered revegetation materials. These are discussed in more detail in Appendix H, *Planting Considerations and Erosion-Control Fabrics*. Plant-material costs depend upon the maturity of the plants purchased. Seed and tubeling stock are sold at a fraction of the cost of more mature stock, although substantially more maintenance is required to guarantee survival. Cost of revegetation may be greatly affected by the lead time a nursery is given to acquire and/or cultivate the materials ordered. Refer to Appendix H for recommended planting densities.

| Plant Material | Unit of Measure | Unit Cost |
|---|---|---|
| Soil Preparation | Square Yard | $2.25 (includes tilling, grading and hand raking) |
| Live Cuttings | Each | $2-$5 (planted) |
| Tubelings | Each | $1-$4 (planted) |
| Conservation Plugs | Each | $1-$4 (planted) |
| Grass Seed | Acre | $750 |
| Evergreen Trees (3 ft height) | Each | $15 |
| | | |
| Deciduos Trees (3/4" caliper) | Each | $20 |
| | | |
| Shrubs (1-2 gallon) | Each | $8-$12 |
| Ground Cover (1 gallon) | Each | $8-$10 |
| Mulch | Square Yard | $2-$5 |
| Hydroseeding | Square Foot | $0.04 |

*Table L-3. Range of costs for plant materials applied in streambank-protection projects.*

## Monitoring, Maintenance and Mitigation Costs

Streambank-protection projects also require maintenance and monitoring, which are discussed in Appendix J, *Monitoring* and under each individual technique in Chapter 6, *Techniques*. Costs for maintenance and monitoring are site-specific and depend upon the degree and frequency of activity. Maintenance costs are generally variable and unpredictable, while monitoring costs are dictated largely by the amount of time spent monitoring and the techniques used. Reporting requirements associated with monitoring activities generally cost about the same as the monitoring activity itself.

Mitigation may also be a required component of streambank-protection projects. Mitigation costs may add significantly to total project costs. For this reason, it is imperative that project managers consider the full extent of mitigation required for a protection project while developing designs and costs estimates. For further discussion of mitigation, refer to the matrices presented in Chapter 5, *Identify and Select Solutions* and to individual techniques presented in Chapter 6.

## RELATIVE COST OF BANK-PROTECTION TECHNIQUES

For the purposes of comparison, overall costs for a given bank-protection technique are expressed in linear-foot or bank-face-foot units. Linear-foot costs are calculated by dividing the total cost by the length of the bank protected. For bank-protection projects that have repeating components up the bank, such as reinforced soil lifts, costs may be expressed as "cost per square foot of bank face." Applying this approach, costs for new projects, particularly those with variable bank heights, can be reliably estimated using known costs for an established protection technique.

### Cost Ranges for Streambank-Protection Techniques

*Table L-4* shows the estimated cost ranges for various bank treatments installed primarily in Washington State between 1995 and 2000. Costs are for materials and construction only and do not include design or postconstruction components of the project. Cost ranges in many cases vary considerably. Where site- or materials-specific factors are too widely scattered in values, their units of measure and costs are expressed at "not applicable." Because any given technique can be applied to a variety of channel circumstances, cost ranges can sometimes span an order of magnitude difference. For example, a drop structure across a small stream may be installed for as little as $100, while a drop structure constructed across a large river may cost upwards of $40,000. Furthermore, site-specific construction considerations (refer to Appendix M) and materials availability can greatly affect project costs. For these reasons, the costs listed on *Table L-4* should be considered rough estimates and should be used only on a conceptual basis for the purposes of comparison.

| INSTREAM FLOW-REDIRECTION TECHNIQUES | | |
|---|---|---|
| **Material** | **Unit of Measure** | **Unit Cost** |
| ***Rock Materials*** | | |
| Groin (rock) | Each | $2,000 - $5,000 |
| Groin (doloes) | Each | $12,000 - $45,000 |
| Buried Groin (rock) | Each | $2,000 - $5,000 |
| Barb (rock) | Each | $2,000 - $5,000 |
| Engineered Log Jam | Each | $1,800 - $80,000 |
| Drop Structures | Each | $100-$40,000 |
| Porous Weir | Each | $100 |
| **STRUCTURAL BANK-PROTECTION TECHNIQUES** | | |
| Anchor Points | na | na |
| Roughness Trees | Linear Foot | $40-$80 |
| Riprap | Linear Foot | $30-$90 |
| Log Toe | Linear Foot | $20-$60 |
| Rock Tow | Linear Foot | $20-$40 |
| Log Cribwalls | Linear Foot | $250-$350 |
| Artificial Streambank-Protection Materials and Systems | na | na |
| **BIOTECHNICAL BANK-PROTECTION TECHNIQUES** | | |
| Woody Plantings (at 3 ft spacing) | Acre | $25,000-$30,000 |
| Herbaceous Cover | Acre | $7-$15 |
| Soil Reinforcement | Linear Foot | $50-$400 |
| Coir Logs | Linear Foot | $8-$30 |
| Bank Reshaping | Linear Foot | $10-$45 |
| Fascines | Linear Foot | $8-$120 |
| Brush Layers and Mattresses | Linear Foot | $37-$50 |
| **INTERNAL BANK-DRAINAGE TECHNIQUES** | | |
| Subsurface Drainage Systems | na | na |

*Table L-4. Estimated cost ranges for various streambank-protection techniques.*

## CASE STUDIES

Three case studies of recently constructed projects in Washington State are provided to give cost exampes of various bank-protection projects.

### Salmon Creek: Clark County, WA - Rock Toe, Soil Reinforced Lifts and Vegetation.

This project is an effort to implement bank protection that is sensitive to fish and wildlife habitat and addresses long-term bank stability. Bank protection was installed at approximately 20 streambank sites within the Salmon Creek drainage system to provide long-term protection of predominantly private property. Bank stability, riparian and fish and wildlife values were addressed as well as hydraulic/hydrologic condition. Width and depth of the channel varies. Average width is approximately 20 feet, and average depth is approximately five feet.

Most sites within the project area incorporated a rock toe with reinforced soil lifts and vegetation. Bank height varied from four to six feet, and protection measures included two to four soil lifts. A rock toe offers relative permanence to the bank location, while soil-reinforced lifts offer immediate protection against all flows and a long-term opportunity for healthy native riparian vegetation to thrive. *Figure L-1* shows one of the project sites after construction.

*Figure L-1. Salmon Creek bank protection using rock toe, soil-reinforced lifts and vegetation.*

Project access was generally provided through privately owned, single-family residences with moderately sloped back yards. Access did not present any particular limitations to materials or equipment. Site restrictions included limiting disturbance to residential property.

Project components consisted of rock toes and soil reinforced lifts planted with riparian grass-seed mix and vegetative cuttings. Materials included existing soils, imported angular rock, coir fabric (woven and nonwoven), wooden stakes, riparian grass-seed mix, willow and dogwood cuttings. Equipment used on site included dump trucks, a loader and a tracked excavator. No dewatering was used. Sediment control consisted of temporary in-channel silt barriers.

The average cost per foot of treated bank was approximately $100 (linear foot of bank), translating to an average of $10,000 per site, not including design, permitting or mobilization.

## Whatcom Creek: Whatcom County, WA - Engineered Log Jams

Large wood was used to enhance cutthroat trout habitat within Whatcom Falls Park near Bellingham. Project objectives focused on creating low- and high-flow cover habitat and areas where spawning gravel could deposit within the bedrock-confined channel. This work followed clean up of a large pipeline gas spill and fire. The two-year return interval discharge is 628 cfs. The channel has a variable width within the steeply incised channel of between 90 and 30 feet. Bedrock controls the grade and width within the project reach.

Access to the channel was limited by steep, forested terrain and offered no opportunity for constructing temporary roads. The site was accessed using a spider hoe or walking/legged, all-terrain excavator.

Project components included installation of three engineered log jams. *Figure L-2* shows the project after construction. A Hilti® fastening system was used to drill and cable trees to key rocks. The increased ballast was used to simulate the drag force obtained by using trees with rootwads. All wood used was from felled trees adjacent to the creek. Galvanized-steel core cable and cable clamps were used to anchor the large wood in place. Other equipment used included: battery-operated Hilti® drill, glue, chokers and a winch mounted on the walking excavator used by workers to pull themselves out of steep areas. No dewatering was used.

*Figure L-2. Engineered log jams on Whatcom Creek.*

The cost for installing three log jams (using on-site large woody debris) was approximately $9,000, not including design, permitting or site access costs. The estimated cost to accomplish the same project with imported, two-to three-foot-diameter, large woody debris was $27,000.

## Nooksack River: Whatcom County, WA - Groins

This project involved constructing groins along two eroding bank sites on the Nooksack River. Groins were constructed of rock; large, concrete, armor units, or "doloes"; and large wood to provide habitat value for salmonids while preventing further erosion into agricultural land. The Nooksack River at this site is a rapidly changing channel with frequent shifts in dominant channel location and orientation. Bank protection was deemed necessary to protect private agricultural land and to prevent a potential large-scale channel avulsion.

Two separate sites were protected. The first site, a 2,100-foot reach, consisted of concrete dolo groins constructed using a large-diameter, angular-stone foundation, with large doloes on the upper portion to simulate and trap large wood. The concrete dolo groins form permeable "noses" that collect woody debris more readily than the nonporous, all-rock, groin type (see *Figure L-3*). The second site, a 1,000 foot reach, consisted of 10 woody groins constructed of 16-inch-diameter (minimum), untreated timber pilings installed to a 25-foot depth, cross logs and rootwads with riprap scour protection at the base of each groin (see *Figure L-4*).

*Figure L-3. Concrete dolo groins on the Nooksack River.*

*Figure L-4. Woody groins on the Nooksack River.*

Unrestricted access to the site was available using existing county and private roads. Access roads along the bank were created.

Project components included constructed groins, installed woody debris among groins, resloping and revegetation of bank slopes between groins, and a detailed monitoring and maintenance program. Materials for the concrete-dolo groins included large-diameter (four-foot) angular rock; large, concrete armor units (25 to 40 per groin); imported woody debris; and rootwads cabled to ecology blocks with braided cable and clamps. Materials for the woody groins included straight timbers, logs with rootwads and cables. The project also included bank resloping, included hydroseeding with grass species, installing unrooted willow cuttings and planting bare-root riparian trees and shrubs. In addition, cutback trenches were incorporated at the ends of treated banks, which consisted of a launchable riprap pad within an excavated and backfilled trench. Equipment included excavators, dump trucks and loaders.

The cost for the dolo-groin treatment was approximately $440 per linear foot of bank. The cost of the woody-groin treatment was approximately $155 per linear foot of bank.

## CREDITS

Figure L-1. Source: Inter-Fluve, Inc.
Figure L-2. Source: Inter-Fluve, Inc.



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