Table B-1 Criteria to achieve functionality of stream channel for salmonid spawning (adults) or rearing (juveniles).

Channel Criteria	Juvenile Coho	Adult Coho	Juvenile Trout	Adult Trout
Minimum depth[1] (inches)	~ 9	~ 7.1 migration[2] ~ 7.1 spawning[2]	~ 12	~ 4.7 (migration)[2] ~ 2.4 (spawning)[2]
Maximum velocity[2] (fps)	< 1	8.04 (migration) 1 – 3 (spawning)	< 0.7	4.02 (migration) 0.25 - 2.4 (spawning)
Substrate preference[2]	Gravel to boulders (0.25 > 12 inch), size and age dependent	0.5 - 4 inch (spawning)	Gravel to boulders (0.25 > 12 inch), size and age dependent	0.24 - 4 inch (spawning)
Temperature (°C)[2]	1.7 (lower lethal) 12-14 (preferred) 26-29 (upper lethal)	7.2 - 15.6 migration 4.4 - 9.4 spawning 4.4 - 13.3 incubation	0.6 (lower lethal) 12-16 (preferred) 22.8 (upper lethal)	6.1 - 17.2 (spawning)
Dissolved oxygen (mg/liter)	> 7.75 (optimum) ≤ 6 (stressful) ≤ 3.5 (lethal)	> 5 migration and spawning[2]	> 7.75 (optimum) ≤ 6 (stressful) ≤ 3.5 (lethal)	> 5 migration and spawning[2]
Max. mean gradient (in reach length of 525 ft)	No data	7%[3]	No data	12%[3]
Cover	Standing crop linked to amount and diversity	Maximum redd distance from cover ≤ 10 ft	Standing crop linked to amount and diversity	Maximum distance of redd from cover ≤ 10 ft
Ratio of scour pool depth (SPD) to jump height (H)	SPD ≥ 1.25 x H	SPD ≥ 1.25 x H	SPD ≥ 1.25 x H	SPD ≥ 1.25 x H
Barrier height (jump at 90° angle)	0.5 ft	7.22 ft (maximum)[2] ≤ 2 ft (optimum)[4]	0.5 ft	2 ft[2] ≤ 1 ft (optimum)[4]

1 In general, channel depth to support migration and spawning must be adequate to cover the maximum body width of the migrating salmonid and is therefore highly size-dependent.

2 Bjornn and Reiser (1991).

3 SSHEAR Program 1997, as found in Thurston County barrier inventory (WDFW 1997).

4 Protocols for assessing fish passage at culverts (Burton, unpublished).

CHANNEL DESIGN AND EXCAVATION

Channel A will be excavated entirely on the former Walter Wetland (see Sheet 3). This new channel will be excavated from Swan Creek at approximately 146 ft downstream of the Pioneer Way culvert to the inlet of the Haire Wetland, which is approximately 300 ft north and 250 ft west of the mouth of the new channel. This new channel will be designed to have a water depth of 6 to 12 inches. A weir will be installed in Swan Creek downstream from the inlet to

Channel A to ensure there is adequate flow through Swan Creek during the summer months. The water elevation at the mouth of the channel is 13.3 ft and a weir will control water flow into the channel. The water elevation at the inlet to the Haire Wetland will be 12.5 ft and controlled by a weir. Channel B will be excavated between the Haire Wetland and Swan Creek at approximately 980 ft downstream of the Pioneer Way culvert. The elevation of this channel at the outlet of the Haire Wetland is 12.5 ft and the elevation of the inlet to Swan Creek is 10.0 ft.

Sideslopes in Channel A and B will be shaped at 2H:1V (see Sheet 4 [A]) The total length of Channel A is projected to be 530 ft, with a watershed length of 453 ft, thereby achieving a sinuosity of 1.17. The total length of Channel B is 43 ft, with a watershed length of 35 ft, thereby achieving a sinuosity of 1.22. Instream structures and habitat will be placed as described in the subsequent section.

Table B-2 Channel specification summary.

	Channel A Swan Creek to Haire Wetland	Channel B Haire Wetland to Lower Swan Creek
Beginning elevation (ft)	13.3	12.5
Ending elevation (ft)	12.5	10.0
Total elevation change (ft)	0.8	2.5
Total length of channel	530 ft	43 ft
Lineal distance of channel	453 ft	35 ft
Channel slope	0.21 percent	5.8 percent
Channel sinuosity	1.17	1.22

IN-CHANNEL HABITAT DEVELOPMENT

Habitat features installed within Channel A will include eight to nine deflector log structures, six to eight logjam structures, six to eight rootwads, and 20 to 30 large boulders (see Sheet 6 [1 and 3] and Sheet 7 [5]). A 1-ft-thick gravel and cobble substrate will be used in this channel and a brush mattress with an optional rock toe will be used to stabilize the banks along the channel (Figure B-2). The deflector log and logjam structures and boulders are proposed along the stream at 25- to 35-ft intervals in order to provide lateral pools and cover, thereby diversifying the instream habitat (see Sheet 3).

Appropriately sorted spawning gravel will be placed in the streambed to create interstitial habitat for invertebrates and potential spawning and rearing habitat for cutthroat trout and coho salmon (see Sheet 4 [A]). It must be noted that the elevations provided in Table B-2 refer to the final elevation of the channel bottom, after the channel has been filled with gravel. Gravels in the 0.25- to 3-inch size range will be used to line the bottom of all channel segments to an average depth of 1 ft (see Sheet 4 [A]). This depth is necessary to ensure that the gravels are usable by cutthroat and coho for spawning.

An evaluation of sediment transport capacity of the channel demonstrates that the normal range of expected flows (1 to 10 cubic feet per second [cfs]) will flush out silt and sand from the pools while leaving the spawning gravel unmodified. Ordinary high flows of 5 cfs would be sufficient to flush out 2-mm sediment and smaller (sands, silt, and clay) from the spawning gravel. An extreme flow of 50 cfs within Channel A would transport sediments up to 12 mm in diameter; thus, gravels placed within the channel would not be dislodged over the range of flows anticipated through the channel.

Habitat features installed within Channel B will include three rootwads, three weirs, and cobble and gravel substrate. Rootwads will be placed in the bank at approximately 25-ft intervals on opposite sides of the bank (see Sheet 3and 6 [1]). The weirs will be made of log sections that will be 9 ft long and secured into the excavated channel by footer rocks underlying the downstream end of each log, and by backfilling over the outer 2 ft of each log (see Sheet 6 [2]). Log placement will create a series of step pools designed to maintain a minimum water depth of 6 to 12 inches at low-flow conditions (see Sheet 4 [2]). The logs will be placed every 10.5 ft for a total of 3 weirs. This arrangement will limit the maximum drop to approximately 4.8 inches, ensuring that none of the log structures limits fish passage for salmonid fingerlings and fry. A single layer of cobble (3 to 6 inches) will also line each step pool to provide for rearing habitat and to minimize scour. Given the necessity for cobble lining in these areas and the desire to maintain a pool depth that exceeds the mean channel depth, the initial lining with gravel in each step pool (i.e., immediately downstream of each log) will not exceed a thickness of 3 inches; the cobble will thus overlie the gravel in these areas.

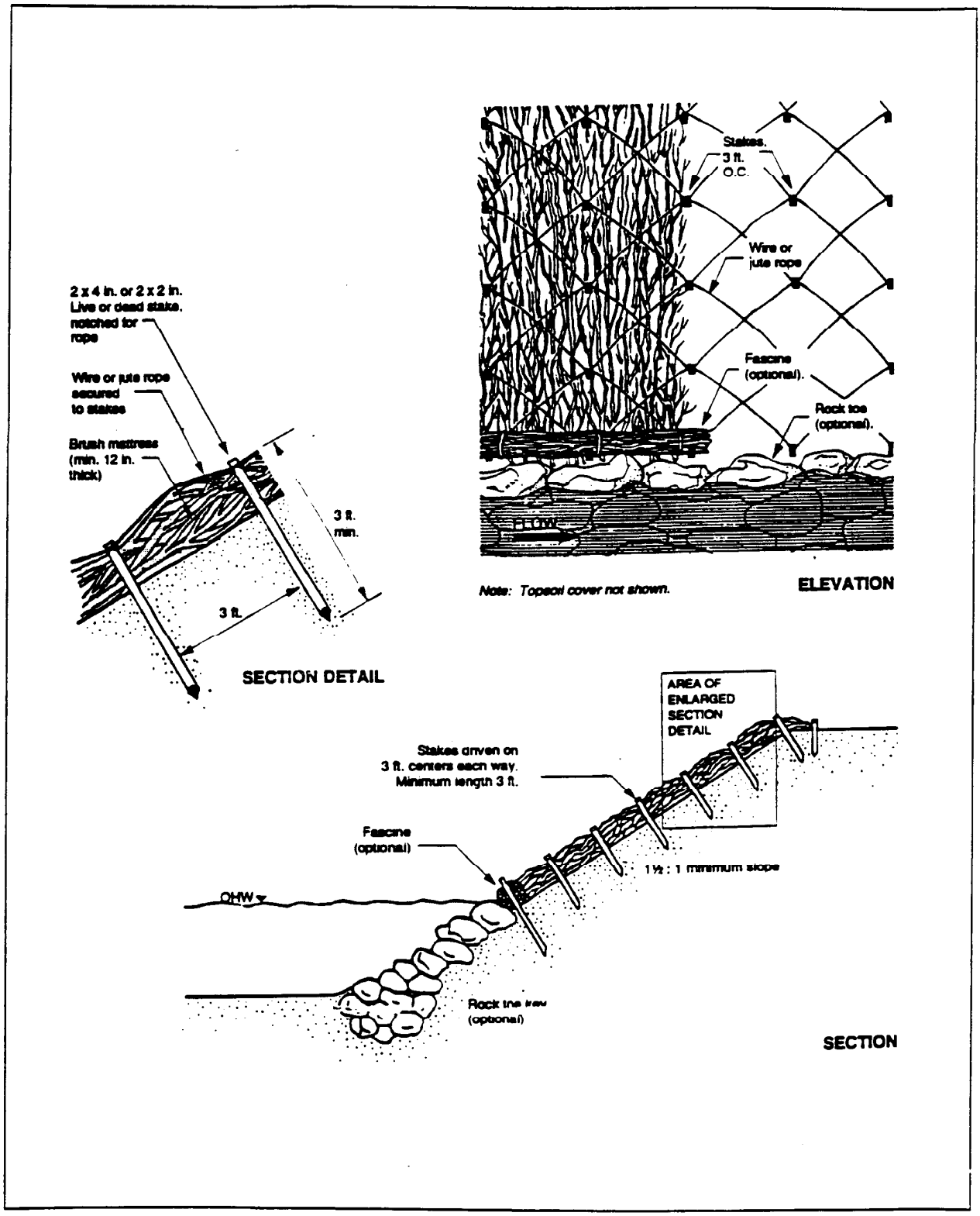

Figure B-2 Installation of a brush mattress shown with an optional fascine and rock toe. (Adapted from Gray and Leiser 1982.) (From Johnson and Stypula 1993.)

Two flow-constrictor log structures will be installed in Swan Creek between 1,050 ft and 1,150 ft (distance measured from the Pioneer Way culvert) (see Sheet 6 [4]). These structures are designed to increase flow velocity in this reach and therefore flush out sediment. Additionally, rock of diameter 0.25 to 4 inches will be placed in the streambed to create interstitial habitat for invertebrates and potential spawning and rearing habitat for cutthroat trout and coho salmon (see Sheet 7 [6]).

RIPARIAN, WETLAND, AND UPLAND HABITAT PLANTING PLAN

The goal of the proposed planting plan is to enhance the structural complexity and diversity of existing plant communities. This goal will be achieved by removing and replacing invasive species with native plants typically and historically found in palustrine wetlands and adjacent forested uplands in the Pacific Northwest region. Enhancing and restoring native plant communities will improve the natural biological support functions of both wetland and upland plant communities. In addition, the existing and created wetland complex will improve the water quality protection and flood storage and attenuation functions compared to existing conditions. Furthermore, the native plant communities are expected to provide instream and overhead cover and a source of terrestrial insects to salmonids and other fishes that use Swan Creek.

Plant Material

All material to be used will be plants native to the Northwest. Much of the native plant material will be obtained from plant nurseries. If season, weather, and soil conditions allow, bare-root plants may be used. Bare-root stock is recommended only for riparian restoration areas, including plant Communities A, C, and D (see Sheet 5 and Appendix C of this report). Otherwise, containerized plants will be used, except where willow, black twinberry (*Lonicera involucrata*), black cottonwood, and red-osier dogwood live stakes are specified. To the maximum extent practicable, black cottonwood, Sitka willow, black twinberry, and red-osier dogwood cuttings will be obtained on site from locations where mature plants of these species are abundant. Collections of cuttings from on-site sources will be done by a wetland ecologist or mitigation specialist to ensure that donor plants are not decimated. Plant substitutions may be allowed based on the recommendation of a project biologist or mitigation specialist, or by permitting agency. Substitutions also may be based in part on plant availability.

All species selected for planting are well-adapted to anticipated moisture and climate conditions, and are expected to thrive following successful establishment. Typical planting details and plant schedules (see Sheet 5) have been developed for each plant community identified in the field investigation that will be restored or enhanced. Many of the different sizes and types of plants specified in these areas have been selected because they were observed on the site or appear to be well-suited to conditions and project goals and objectives.

Planting Density

Spacing of trees and shrubs varies depending on planting location, vegetation zone, plant type (tree or shrub), and growth habit. It is assumed that the highest planting densities will be used in the southern portion of Community A, which is expected to be cleared of most existing vegetation to construct the proposed off-channel and wetland habitat. Lowest densities are specified for dense, second-growth, deciduous, upland forest communities (Communities C and D). See the typical planting details and plant schedules (see Sheet 5) for specific densities and species of plants to be used in each community.

Site Preparation

Soils within each community will be modified where necessary to maximize native plant establishment success. Decisions on whether soil amendments will be required will be determined at the time of planting by the consulting biologist or mitigation specialist. If during excavation, it becomes apparent that soil organic matter content in any of the enhancement or restoration areas is unfavorable to native plant establishment, soils in the immediate vicinity of all bare-root, container-stock, and rooted-cutting plantings will be amended with topsoil and mulch, as specified by the consulting biologist or mitigation specialist to promote successful establishment and growth. It is assumed that soil in the immediate vicinity of live-stake plantings will not need amending based on preliminary reconnaissance investigations for communities in which live stakes have been specified (see plant schedules).

Clearing, grading, and any soil amendments of the off-channel and wetland creation areas in Community A shall not occur when the ground is frozen or excessively wet. Following installation of bare root or containerized plants, a 3- to 4-inch layer of medium-fine bark mulch, compost, or equivalent material will be applied within a 2- to 4-ft radius of each shrub and tree,

Proposed Native Plant Community Enhancements

Below are the descriptions of the proposed enhancement within each community to be enhanced. The general limits of the enhancement and restoration within each community are shown on Sheet 5. Limited enhancement is proposed within Community E, as described below. No enhancement is proposed in Communities B and F. As indicated in the sections below, detailed plans for each community are shown in the typical planting details, typical sections, and plant schedules (see Sheet 5).

Community A

Prior to introducing native plants, all invasive species will be removed, including cherry laurel, Scot's broom, Himalayan blackberry, one-seeded hawthorn, and English ivy. A bulldozer or other excavator will be used to remove most of these species. To the maximum extent practicable, mature black cottonwoods and existing snags will be saved. English ivy will be removed (or a section of the stems removed to kill the plant) from all of the infested black cottonwoods that can be saved. Those snags and trees that cannot be saved will be used as habitat features in Community B or other communities on the site.

Stream Channel—An approximately 530-ft-long channel connecting Swan Creek to Haire Wetland will be constructed. This channel is expected to divert a portion of high flows from Swan Creek into this high-flow refuge habitat during the fall, winter, and spring.

Zone 4 is located upslope of Stream Channel A in adjacent uplands. Shrubs, arborescent shrubs, and trees will be planted in this zone, including Pacific ninebark, Pacific willow, Western crabapple (*Malus fusca*), Oregon ash (*Fraxinus latifolia*), black cottonwood, Sitka spruce (*Picea sitchensis*) and western red cedar (*Thuja plicata*). Cottonwood and conifers will be planted in upslope areas in Zones 4 and 5 to provide shading and bank stability (see planting detail for Communities A, C, and D and typical planting section for Community A-Constructed Wetland and Stream Channels). Together these plantings will create a more structurally diverse assemblage of native plants that provide breeding, feeding, and resting opportunities to many species of wildlife typically found in the western Washington. All of the species specified in these planting details are typically found in lowland wetland and upland plant communities in

western Washington. Spacing and densities of plants specified in the planting schedules for Community A are typical of those observed in plant communities within the Puget Sound region.

Constructed Stream Channel Zones (C1 and C2)—As shown on Sheet 5, inlet and outlet channels will be constructed to the Haire Wetland. Two planting zones will be established in the constructed channel area (Zone C1 and Zone C2). Zone C1 will extend from the OHWM upslope to near the top of bank. Zone C2 will extend from near the top of bank outward as shown in the planting detail and typical section for Zones C1 and C2. A combination of shrubs and trees will be used to create a mosaic of shrub and forest communities in these zones. Shrubs and trees often associated with streams and wetlands that are widely recognized for their rapid growth and bank stabilization characteristics have been selected for Zone C1, including red-osier dogwood, black twinberry, Pacific ninebark, Hooker willow (*Salix hookerina*), and Pacific willow. These species will provide bank stability and overhead cover relatively rapidly. Shrubs and trees selected for Zone C2 were selected in part for their rapid growth characteristics, as well as their tolerance of summer drought and growth forms. Snowberry, red elderberry (*Sambucus racemosa*), and vine maple (*Acer circinatum*) will form three tiers of shrub vegetation beneath the mixed deciduous and coniferous forest canopy formed by red alder, Oregon ash, Sitka spruce, Douglas fir, and western hemlock (*Tsuga heterophylla*). Berries and seeds of these species will provide food for a variety of wildlife and the vegetation will provide cover.

South of Channel A—An approximately 0.5-acre upland area south of Channel A (Zone 6) will be converted from primarily driveways and invasive species to upland forest. It is assumed that this area will be totally cleared and may be used to stockpile construction materials and equipment and as a staging area for constructing Channel A. Prior to using this area for these purposes, all invasive vegetation will be removed. Mature black cottonwoods will be saved wherever possible in this area.

Because all of the area south of Channel A will be cleared of vegetation, it will have to be more densely planted to prevent regrowth and spread of invasive species. The forest stand structure has been built around retention of existing black cottonwood trees. A mixture of deciduous and evergreen trees will be used to establish a multiple layered forest canopy. Madrone (*Arbutus menziesii*) and scattered Douglas fir and red alder will be used in the more open areas now occupied by buildings, meadow vegetation, and driveways. Shade-tolerant shrubs, including vine maple and hazelnut (*Corylus cornuta*) will be planted beneath existing

cottonwoods. A mixture of salal (*Gaultheria shallon*), tall Oregon grape (*Mahonia nervosa*), Indian plum, and oceanspray (*Holodiscus discolor*) will be planted between madrone, red alder, and evergreen trees as shown in the typical planting detail for this area. As shown in the plant schedule for Zone 6, a variety of ages (sizes) of trees will be used to create a more diverse stand structure and habitat.

Public Access Zone (Zone PA)—This community will border the public access trail, the mixed deciduous and coniferous forest in Zone 6, and Swan Creek. The assemblage of plants selected for this community provides different food and cover opportunities to wildlife than other community types, is aesthetically pleasing, and will deter people from trampling the banks of Swan Creek. Several species of trees and shrubs produce fruit eaten by wildlife commonly found in the Puget Sound region. Armed species, including Nootka rose (*Rosa nutkana*), Douglas hawthorn (*Crataegus douglasii*), and western crabapple, form dense thickets that will deter access to the west bank of Swan Creek. As with other communities, a mixture of different sizes of trees and shrubs will be used to create greater habitat and structural diversity (see Plant Material Schedule Community A – Zone PA). These species also will enhance existing overhead cover, provide better shade, and more breeding, feeding, and rearing opportunities of fish and wildlife than now exist along this reach of the creek.

Community B

No enhancement is proposed in this area, which contains dense shrub and deciduous forest communities around its perimeter. This area is a good source of willow, red-osier dogwood, black twinberry, and cottonwood cuttings that will be used for enhancing vegetation in Communities E and G as well as Zone C1 of the Constructed Stream Channel.

Although no plantings will be done in this community, large logs or stumps with rootwads attached will be placed in eight widely separated locations, 80 to 100 ft apart. Logs should be a minimum of 18 inches in diameter and 10 to 20 ft long. Logs will be installed by either mechanized equipment through either Communities C or D, or lowered in by helicopter. The logs and stumps will enhance habitat quality by providing resting areas and foraging habitat for frogs, reptiles, birds, and small mammals. As these features decompose, they also may provide breeding habitat for various species of wildlife, including woodpeckers, mice and voles, salamanders, and garter snakes.

Communities C and D

Reforestation will occur in Zones 4 and 5 of Communities C and D. Following removal of dense thickets of Himalayan blackberry, coniferous trees, including Douglas fir, Western hemlock, grand fir, western red cedar, and Sitka spruce, will be planted within the existing deciduous forest. Zone 4 is the area adjacent to the wetland and extends upslope to approximately the 20-ft contour (see Sheet 5). This zone is expected to be somewhat more mesic (wetter) habitat than Zone 5, which is located upslope. Sitka spruce and western red cedar, which are shade-tolerant and will tolerate moister soil conditions, will be placed in Zone 4. Douglas fir, western hemlock, and grand fir (*Abies grandis*) will be planted in Zone 5. Douglas fir, which is shade-intolerant, will be planted only in areas where the deciduous forest canopy is more open. Western hemlock and grand fir, which are shade-tolerant will be planted in areas beneath the denser deciduous forest canopy. Conifers will be planted in both zones in small groups and as scattered individuals. To simulate the multiple-tiered and age structures of naturally regenerated forests, different ages and sizes of conifers will be planted as specified in the plant schedules for Zones 4 and 5 (see Plant Materials Schedule – Communities A, C, and D for Zone 4 and Zone 5). This will contribute to greater habitat diversity in forest stand structure by creating small stands of conifers of mixed ages and heights as well individual conifers amidst stands of deciduous trees. In addition, the shade that the conifer stands will provide will help control the spread of invasive species, particularly Himalayan blackberry and Scot's broom, which are generally shade-intolerant.

Community E

A limited amount of enhancement will occur in Community E. Cuttings of shrubs collected on site will be planted on both banks of Swan Creek near to where it exits the property. Prior to planting these areas, similar to that shown in the typical detail for Constructed Stream Channel Zone C1, the reed canarygrass will be removed by hand. Where reed canarygrass has been removed, groups of live stakes of Sitka willow, red-osier dogwood, and black cottonwood will be planted to create a dense scrub-shrub and forested wetland community that will shade out the reed canarygrass. Sources of cuttings will include plants from Communities B and F.

Community F

No enhancement is proposed in this area, which contains dense scrub-shrub and deciduous forest vegetation. This area is a good source of willow, red-osier dogwood, black twinberry, and cottonwood cuttings.

Community G

Sitka willow, black cottonwood, red-osier dogwoods, and Oregon ash will be installed in this community. Plants will be in the form of both cuttings and ball-and-burlap seedlings. Above- and below-ground portions of reed canarygrass will be removed entirely within 4-ft-diameter circles evenly distributed across the community. Removal will be achieved by hand-shoveling. The intent of this planting method is to grow trees and shrubs that will eventually shade out the reed canarygrass.

SUMMARY

This project will provide approximately 2,249 ft^2 of instream rearing habitat for all species of juvenile salmonids, and spawning habitat for adult coho and cutthroat trout. A detailed list of materials required for construction of the two new channels is shown in Table B-3.

The combined enhancement and restoration activities will improve over 5.8 acres of fish and wildlife habitat, including the following:

- 4.3 acres of riparian forest will be restored or enhanced.
- Provide access to 3 acres of existing wetlands for salmonid rearing habitat.

The project includes removal and control of over 1.8 acres of invasive species in five different areas that now provide limited habitat value. In addition, about 0.5 acre of habitat will be created where very little or no habitat currently exists. Proposed restoration activities will remove about 0.5 acre of existing driveways, buildings, and invasive or ornamental plants in previously filled areas of the site.

Table B-3 Summary of construction materials.

Item Description	Approximate Quantity	Units
Earth work	6,200	Yd^3
Streambed gravel (0.25- to 3-inch-diameter stone)	65	Yd^3
Cobbles (3- to 6-inch-diameter stone)	10	Yd^3
Boulders (12- to 18-inch-diameter stone)	60	Each
Logs for log weirs (9-ft length x 16-18-inch diameter)	6	Each
Logs for triangular structures (10-ft length x 12- to 18-inch diameter)	56	Each
Rootwads 6-ft length x 12- to 18-inch diameter	11	Each
Jute matting	11,460	Ft^2
Hydroseed	0.50	Acres
Live stakes	100	Each

REFERENCES

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

WDFW (Washington Department of Fish and Wildlife). 1997. Thurston County barrier culvert inventory. WDFW, Olympia.

WDFW (Washington Department of Fish and Wildlife). 1999. Priority habitats and species database, habitat and species map for Poverty Bay quad, 4712233; Tacoma South quad, 4712224; and Tacoma North quad, 4712234. WDFW, Olympia.

WDFW and WWTIT (Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes). 1994. 1992 Washington State salmon and steelhead stock inventory. Appendix One: Puget Sound stocks north Puget Sound volume. WDFW and WWTIT, Olympia.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization, volume 1, Puget Sound region. Washington State Department of Fisheries, Olympia.

Appendix C— Existing Habitat Conditions in the Project Area

APPENDIX C
EXISTING HABITAT CONDITIONS IN THE PROJECT AREA

FISH HABITAT

Fish habitat surveys were conducted to provide baseline environmental data that would form the basis for identifying specific design objectives for the proposed restoration project. The intent of the study was to characterize both positive and negative aspects of the existing habitat conditions on the site. Beneficial habitat conditions would be protected and preserved through the construction process while negative conditions would be specifically targeted by the design effort. Fish habitat was evaluated in Swan Creek from the outlet of the Pioneer Way culvert to the inlet of the Northern Pacific Railroad culvert (Figure C-1). This section of Swan Creek was divided into four reaches based on habitat type (Figure C-1). Fish habitat was rated based on stream channel types and the conditions of both spawning and rearing habitat.

Methods

The current fish habitat conditions were determined using a habitat unit survey method similar to that described by Hankin and Reeves (1988), and the location of any barriers that could prevent movement of adult or juvenile salmonids were identified during the survey. The following habitat elements were examined: embeddedness (percentage fine sediment composition) of spawning gravel, percentage pool area, pool depth and cover class, dominant and subdominant substrate, and large woody debris (LWD).

In each survey reach, pools were tallied by depth category, pool tailouts were examined for the presence of spawning gravel, and the amount of spawning-gravel embeddedness was visually estimated by a habitat biologist. Pool depth categories were 0 to 7 inches, 7 to 14 inches, 14 to 28 inches, and 28 to 45 inches. Spawning gravel was defined as a patch of gravel containing particles ranging from 1 to 3.5 inches in diameter that covered a minimum area of 0.3 ft^2. Embeddedness estimate categories were less than 30 percent and greater than 30 percent.

An inventory of LWD was performed to provide information for an assessment of LWD functions relative to the formation of fish habitat. In each survey reach, all pieces of LWD observed within the bankfull influence zone were counted. Pieces of LWD were subdivided into

three size groups (4.5 to 14 inches, 14 to 28 inches, and greater than 28 inches) based on the estimated diameter at the large end of each piece. Each LWD structure (single piece or logjam) was identified, and the number of LWD pieces in each structure was counted.

Habitat Quality Ratings

Channel Types

Stream channel type influences the amount and quality of fish habitat in a stream. Stream channel types defined by Montgomery and Buffington (1993) based on physical properties and channel dynamics include the following: pool-riffle, forced pool-riffle, plane-bed, step-pool, braided, and regime. Substrate type is also a factor in habitat quality, because it influences invertebrate productivity.

A pool-riffle channel has an undulating bed featuring a sequence of sediment bars, pools, and riffles. Pool-riffle and forced pool-riffle channels tend to have a pool:riffle ratio of 1:1; this ratio results in sufficient pools to provide spawning and rearing habitat for fish and sufficient riffles to provide fertile habitat for invertebrate populations. The quality of the rearing habitat, however, depends on channel width and depth. A wider channel tends to have deeper pools, which are more beneficial to fish. Gravel substrates common in these two channel types are conducive to invertebrate productivity.

Plane-bed channels have a higher percentage of riffles than of pools; therefore, the amount of fish habitat is lower than in the pool-riffle and forced pool-riffle channels. On the other hand, step-pool channels have a higher percentage of pools than of riffles. Step-pool channels provide good fish rearing habitat but lack the substrate and riffle area needed for adequate invertebrate productivity.

Braided and regime channel types generally do not have a high percentage of spawning and rearing habitat. Braided channels have variable substrate; therefore, invertebrate productivity is also variable. Sandy substrates common to regime channels inhibit invertebrate productivity. A regime channel is a low-gradient channel characterized by sediment deposition.

Spawning Habitat

Ratings of spawning habitat quality were based on the embeddedness of the spawning gravel (Table C-1). Embeddedness is a subjective and is determined visually. When silt is present in spawning gravel in amounts greater than 30 percent, the embryo survival rate can be reduced to as low as 28 percent (Raleigh et al. 1984).

Table C-1 Criteria for rating fish habitat quality.

Parameter (source)	Habitat Quality Rating		
	Poor	Fair	Good
Spawning habitat			
Embeddedness (Martin 1996)	> 60 percent of sites with embeddedness > 30 percent	> 60 percent of sites with embeddedness < 30 percent	> 60 percent of sites with embeddedness < 5 percent
Rearing habitat			
Percentage pool area (Raleigh et al. 1984)	< 20 percent or > 70 percent	20 - 30 percent	30 - 70 percent
Pool depth and cover class (similar to Raleigh et al. 1984)	> 30 percent are < 7" deep and < 30 percent are LWD-formed	> 30 percent are > 7" deep and 30 - 60 percent are LWD-formed	> 60 percent are > 28" deep and > 60 percent are LWD-formed
Dominant substrate for food production (Raleigh et al. 1984)	Gravel-dominant and sand-subdominant or boulder-dominant	Gravel-dominant and cobble-subdominant or cobble-dominant and boulder-subdominant	Cobble-dominant and gravel-subdominant
LWD (Martin 1996)	< 1 pieces/channel width	1 - 2 pieces/ channel width	> 2 pieces/ channel width

Rearing Habitat

The following rearing habitat parameters were rated according to the criteria shown in Table C-1: percentage pool area, pool depth and cover class, dominant and subdominant substrate, and LWD. Pools are important for providing resting areas and refuge for juvenile fish; pool depth influences the area available to fish for refuge. Cover class is dependent on whether a pool is formed by LWD; the presence of LWD in pools increases the amount of cover available to fish for refuge. In addition to providing cover, LWD helps to form pool habitat by influencing

channel hydraulics. Dominant and subdominant substrate types influence food production; a substrate that is cobble-dominant and gravel-subdominant provides the best habitat for maintaining a diverse invertebrate population.

Results

The results of the habitat unit survey are presented in Table C-2 and the habitat quality ratings are presented in Table C-3.

Rearing Habitat Quality

Percentage pool area is rated good for Reaches 1, 2, and 4. Percentage pool area for Reach 3, which has a regime channel and consequently a naturally low number of pools, is rated fair. The low amount of pool area in Reach 3 is partly a function of the low gradient and the low amount of LWD.

Pool depth and cover class is rated fair for Reaches 1 and 4. Reach 2 has a fair to good rating for pool depth and cover class because the majority of pools in this reach have depths less than 45 inches. The rating for pool depth and cover class for Reach 3 was poor. Pool depth is directly related to stream size; the pools in Reach 3 are naturally shallow because the stream width in this reach is less than 10 ft.

Dominant and subdominant substrate for food production is rated poor for Reaches 1, 2, and 3 because the dominant substrate in these three reaches is sand. Reach 4 has a good rating for dominant and subdominant substrate because the dominant substrate in this reach is cobble, with gravel as the subdominant substrate. This substrate type is good for invertebrate communities.

LWD is rated good for Reaches 1, 2, and 4, and fair for Reach 3.

Table C-2 Habitat conditions in Swan Creek during summer 1999.

	Reach 1	Reach 2	Reach 3	Reach 4
Channel type	Pool-riffle	Pool-riffle	Regime	Pool-riffle
Gradient range (percent)	1	1	< 1	1
Survey length (ft)	884	369	102	275
Mean bankfull width (ft)	19.2	15.4	9.8	16.2
Percentage of pool tailouts with resident trout spawning gravel	58	15	50	25
Percentage of spawning gravel with embeddedness of				
< 30 percent	21	50	0	0
> 30 percent	79	50	100	100
Number of pools	22	13	2	8
Number of riffles	14	7	4	7
Percentage pool area	56	57	26	32
Pool spacing	2.1	1.8	5.2	2.1
Percentage of pools with residual depth of				
0-7 inches	17	23	0	0
7-14 inches	33	8	50	88
14-28 inches	25	38	50	13
28-45 inches	21	31	0	0
> 45 inches	4	0	0	0
Percentage of pools with LWD as primary former	50	85	0	50
Dominant/ subdominant substrate	Sand/gravel	Sand/fines	Sand	Cobble/gravel
LWD pieces per channel width	7.6	8.1	1.4	2.9
Total pieces of LWD	352	193	15	50

Table C-3 Habitat quality ratings for the four reaches surveyed in Swan Creek during the summer of 1999.

Parameter	Habitat Quality Rating			
	Reach 1	Reach 2	Reach 3	Reach 4
Spawning habitat				
Embeddedness	poor	fair	poor	poor
Rearing habitat				
Percentage pool area	good	good	fair	good
Pool depth and cover class	fair	fair to good	poor to fair	fair
Dominant substrate for food production	poor	poor	poor	good
LWD	good	good	fair	good
Overall habitat quality	fair	fair	poor to fair	good

Overall Habitat Quality

The pool-riffle channel type of Reach 1 provides good spawning and rearing habitat for fish, but the spawning gravel is highly embedded and the substrate type does not provide adequate habitat for food production. Therefore, the overall fish habitat rating for this reach is fair.

The overall salmonid habitat rating for Reach 2 is also fair because of the large percentage of sand and silt in the stream. Sand in the spawning areas causes the spawning gravel to be embedded, and as the subdominant substrate, the sand decreases invertebrate productivity. The depth of the pools (< 60 percent were < 28 inches deep) also contributed to the fair salmonid habitat rating.

The overall salmonid habitat rating for Reach 3, which has a regime channel, is poor to fair. Regime channels inherently have sandy bottoms and a low number of pools; Reach 3 has only one spawning habitat site and inadequate habitat for food production.

Reach 4 has a good overall salmonid habitat rating because the pool area, pool depth and cover, and amount of LWD present provides good habitat for salmonid rearing. Additionally, the substrate type provides good habitat for the invertebrate communities that provide a food source for fish. However, the spawning habitat in this reach is embedded and therefore does not provide good spawning habitat for fish living in this system.