CHAPTER 5: FISH HABITAT

Green Cove basin contains a year-round creek and wetlands with salmon and resident fish species. The fish and fish habitat can be sensitive to stormwater management practices (Bisson 1992). This chapter describes the existing fish and fish habitat in the basin, focusing on salmon. Section 5.1 introduces the fundamentals of salmon habitat; readers already familiar with the basic concepts may wish to skip to the Green Cove Creek salmon habitat survey in section 5.2.

5.1 OVERVIEW OF SALMON HABITAT

Salmon need streams with the specific physical, chemical and biological conditions that comprise their freshwater habitat. Essential physical conditions include adequate cover, resting places, spawning gravel, migration routes, and water depth and velocity. Chemical conditions include high dissolved oxygen, and low temperature and turbidity. Biological conditions include ample leaf litter and aquatic insects. Healthy riparian vegetation and natural stream hydrology often supply these requirements in an undisturbed stream system (Sedell et al 1982).

> **FISH FACTS**
>
> **Anadromous fish** are species that mature in salt water and spawn in fresh water, including salmon, steelhead, and sea-run cutthroat. They use different parts of the stream system for spawning and rearing.
>
> **Resident fish** are species which remain in or near the same water body for their entire life cycle, and do not move back and forth between salt water and fresh water.
>
> **Salmon species** include the five Pacific salmon: chum, coho, sockeye, pink and chinook. Recently, fish biologists reclassified sea-run cutthroat and steelhead from trout to salmon.

The freshwater life stages of salmon include adult upstream migration, spawning, incubation, emergence, rearing, and juvenile downstream migration. Each stage has specific habitat requirements, which may also vary by species. Salmon in all stages need adequate water quality, especially cool water temperature and high levels of dissolved oxygen.

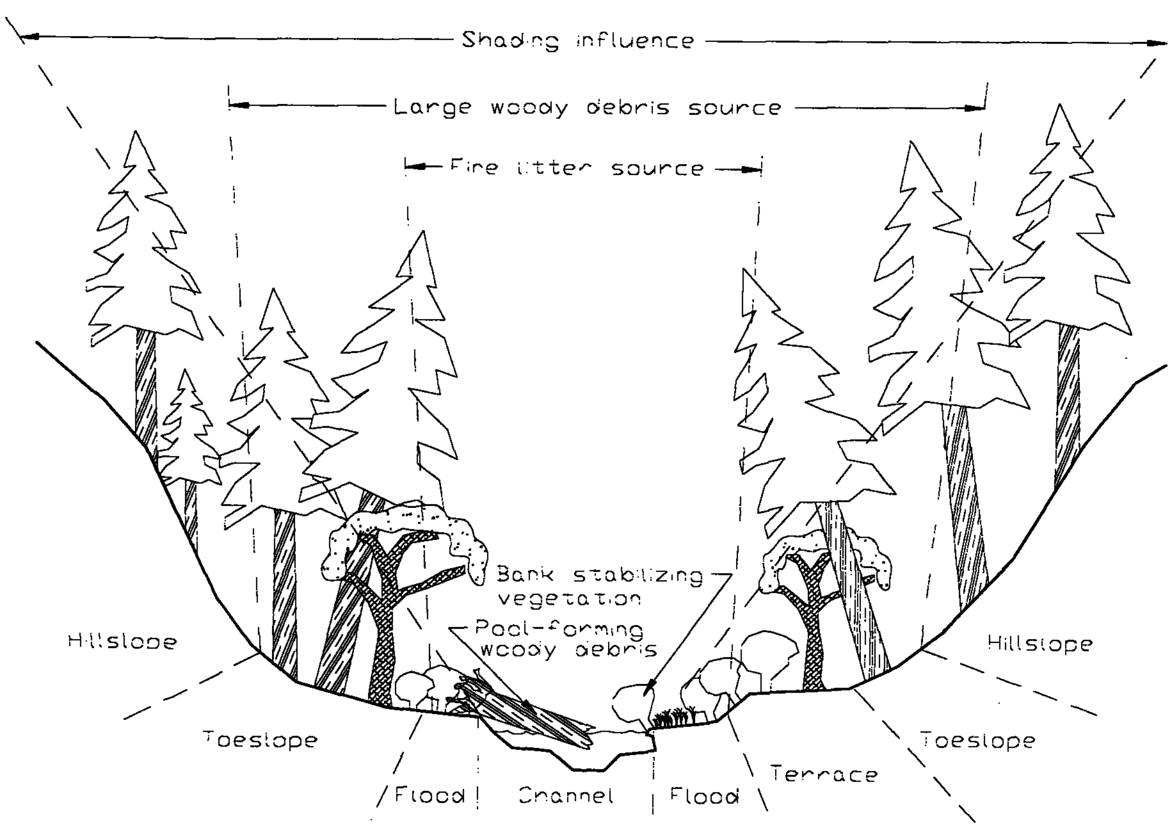
Adult salmon migrating upstream must have sufficient stream flow to reach spawning areas, and open passage through culverts and other artificial barriers. High velocity in culverts and large drops at the outfalls can prevent passage. Spawning salmon need appropriately sized gravel in riffles and pool tailouts, in which to deposit their eggs. Water depth, velocity, and cover influence the selection of spawning sites (Everest et al 1985). A complex stream network of pools and riffles with clean spawning gravel generally indicates good spawning habitat (Bisson 1992).

Spawning sites must remain cool, well-oxygenated and free from fine sediment in order for incubation to succeed. Incubation areas must be protected from scour caused by high peak flows, which can damage or wash away the eggs.

Emerging fry need sediment-free cobbles in the substrate for refuge. Food becomes crucial as the emerging fry mature and absorb their egg sacs. During the rearing period, fry feed in gravelly riffles and rest in pools and slow-water areas with good cover, so evenly distributed, diverse habitat is important. Coho need year-round flows with sufficient refuge areas, including wetlands, and feeding areas, because they remain in the stream to rear for a year. Downstream-migrating juvenile salmon again need adequate flows, cold, well-oxygenated water, and low turbidity.

Riparian vegetation plays a critical role in providing habitat for fish (Gregory et al. 1991) (see figure 5-1 below). Overhanging trees and shrubs supply cover and resting places for fish. Shade from trees and shrubs cools the water which increases its dissolved oxygen capacity. Aquatic insects feed on fallen leaves and needles, and fish, in turn, eat the insects. Fallen trees and roots create pools, trap food, and offer resting places for fish. Live roots stabilize the stream banks and prevent erosion, and trees and shrubs take up water and reduce soil saturation.

Figure 5-1: Fish habitat functions of the riparian zone



Riparian vegetation enhances stream water quality by filtering sediments out of runoff and absorbing large quantities of nutrients, such as nitrogen and phosphorous (Lowrance et al 1984). Riparian soils are especially effective at removing nitrogen from water. Studies in Maryland have found that a 50 foot wide buffer strip between agricultural lands and streams can remove more than 75% of the nitrogen and more than 40% of the phosphorous from sub-surface water before it reaches the streams (Peterjohn and Correll 1984).

Urbanization tends to degrade aquatic habitat by introducing water quality contaminants, reducing riparian vegetation, increasing sediment load, increasing the intensity of winter stream flows and reducing summer base flows (Nelson 1992; Reinelt et al 1990).

5.2 GREEN COVE CREEK SALMON HABITAT SURVEY

County staff surveyed Green Cove Creek from the mouth to Evergreen Parkway in the summer of 1995, in order to evaluate the current fish habitat conditions, identify habitat problems and establish a baseline from which to monitor trends over time. The survey included physical channel measurements, characterization of habitat types, and woody debris counts. The survey method was developed by Aquatic Resource Consultants of Seattle, WA (the Johnson method). In addition, part of one segment was surveyed using the methods described in the *Timber-Fish-Wildlife Ambient Monitoring Program Manual* (Northwest Indian Fisheries Commission 1994), so the two survey methods could be compared.

5.2.1 SURVEY METHODS

This section describes the Johnson habitat survey method. Refer to the T-F-W manual cited above for a complete description of the T-F-W survey methodology. Before going to the field, the stream was divided into segments according to gradient, confinement and stream order. The segmentation was verified in the field, and modified to reflect actual conditions. Maps 11-13 show the final segments.

A 2-3 person team conducted a field survey of Green Cove Creek from the mouth to Evergreen Parkway, in July 1995. The survey team returned in August 1995 and performed the T-F-W survey modules for segmentation, habitat units, reference points and woody debris level 1 on segment 2C, from station 7+60 to station 11+38 (see map 12). A quality assurance team from Northwest Indian Fisheries Commission did a follow-up survey on August 7-8, 1995.

The survey team collected data on wetted width and depth; bankful width; habitat unit type; woody debris size, position and location; channel substrate; water surface and channel bed elevation; and channel bearings.

All vertical measurements were taken with a laser level, using standard survey techniques. Horizontal distances were measured with a calibrated hip chain, and a compass was used to determine the relative bearings and direction changes of the creek. Surveyed locations were tied to a known datum point at each road crossing, wherever possible. Survey shots were taken at each change in habitat type, each change in channel direction, and each significant habitat feature. Wetted width and bankful width were measured with a meter tape, according to the methods of the T-F-W manual.

Habitat types were determined according to the T-F-W method, and pools that failed the T-F-W screens for minimum unit size and residual depth were combined with the adjacent habitat units. Unit widths were measured at each point where the width changed. Woody debris was tallied and sorted into size classes according to the T-F-W level 1 method, but the location (zone) was not recorded. A channel position of lateral, traversing or sill was assigned to each piece. Channel substrate was characterized visually. Flow and temperature data were collected separately from the habitat survey (see Chapters 3 and 4).

The survey team recorded additional information on the size and location of significant bank erosion sites, morphological features such as gravel and sand bars, channel-forming features such as boulders, outfall locations, and trash dumps.

Survey data was mapped in plan view and profile using AutoCad and Boston Harbor civil surveying software. Channel bed and water surface profiles were determined from actual measured elevations. Horizontal distances were checked against known road crossing locations and errors were field-checked and corrected.

Stream segment lengths were converted to "channel units," where the channel unit equals the average bankful width of the segment (for example, a 100-meter long segment that averages 5 meters wide would be 20 channel units long). Channel units were used to define pool frequency and large woody debris density.

The survey results were compared to several habitat indices developed for the Pacific northwest, particularly those contained in the *Standard Methodology for Conducting Watershed Analysis, Version 3.0* (Washington Forest Practices Board 1995). Habitat conditions were compared to the life cycle needs of the salmonids that use the stream.

Fish use and distribution was compiled from existing sources, including: Washington Department of Fish and Wildlife databases on priority habitats and species, salmon spawning ground surveys, salmon fry releases, and game fish releases; interviews with department staff; volunteer stream walk and fish watch surveys; and anecdotal information from basin residents. Fish surveys were not conducted as part of the basin plan study.

Staff returned to the stream in 1996, to fill in data gaps identified during the data analysis and interpretation. The stream was walked from end to end in April and May of 1996 to evaluate the impacts of record high flood flows in February 1996, and changes in woody debris locations, gravel and fine sediment deposition, and new erosion sites were recorded. Random pebble counts and canopy closure measurements were made at the same time.

5.2.2 RESULTS

Maps 11-13 depict the plan views and significant habitat features of the creek. The tables below summarize the habitat survey data, and the figures depict the channel profiles and distribution of pools, riffles and large woody debris. Appendix F contains the complete data sets. The narratives describe the habitat characteristics of each segment.

Segment 1 Habitat

Segment 1 is a distributary channel flowing through a tidal mudflat. The segment extends from the high tide level in Green Cove Creek down through mudflats to the point where the surrounding bluffs drop away into Green Cove. The segment is 421 meters long, with less than 1.0% gradient. Confinement is low, and the segment is shallow with a high width-to-depth ratio characteristic of low-gradient tidal channels.

Segment 1 is dominated by riffle and glide habitat types. The few pools occur mainly toward the upstream end where tidal influence is minimal. Sinuosity is low; the stream tends to follow a straight course down-gradient because tides remove the woody debris, and the highly erodible, unvegetated fine sediments and gravel at the mouth of the creek offer little flow resistance. The habitat complexity is naturally low through the segment.

Large woody debris (LWD) is sparse and unstable because tides carry it away. Most of the woody debris that produces habitat is contained in debris jams comprised of medium and large diameter pieces, heavy enough to resist large flows, located near the upstream end where tides have the least effect. Vegetation is limited to algae, and canopy closure averages 20%. Substrate consists of fine sediment

Figure 5-1 shows the distribution of pools, riffles and woody debris through the segment. The horizontal axis represents the length of the segment, flowing from left to right. The areas below the zero axis represent pools, and the areas above the zero axis represent riffles. The vertical bars represent large woody debris. Large woody debris declines toward the downstream end of the segment and riffles increase correspondingly.

Figure 5-2 shows the channel and water surface profile of segment 1. The channel bed becomes flat and uniform at the downstream end, where no pools occur. The depressions in the channel bed where the pools occur at the upper end tend to be broad and shallow.

Figure 5-1 Green Cove Creek Segment 1 pool, riffle and woody debris distribution

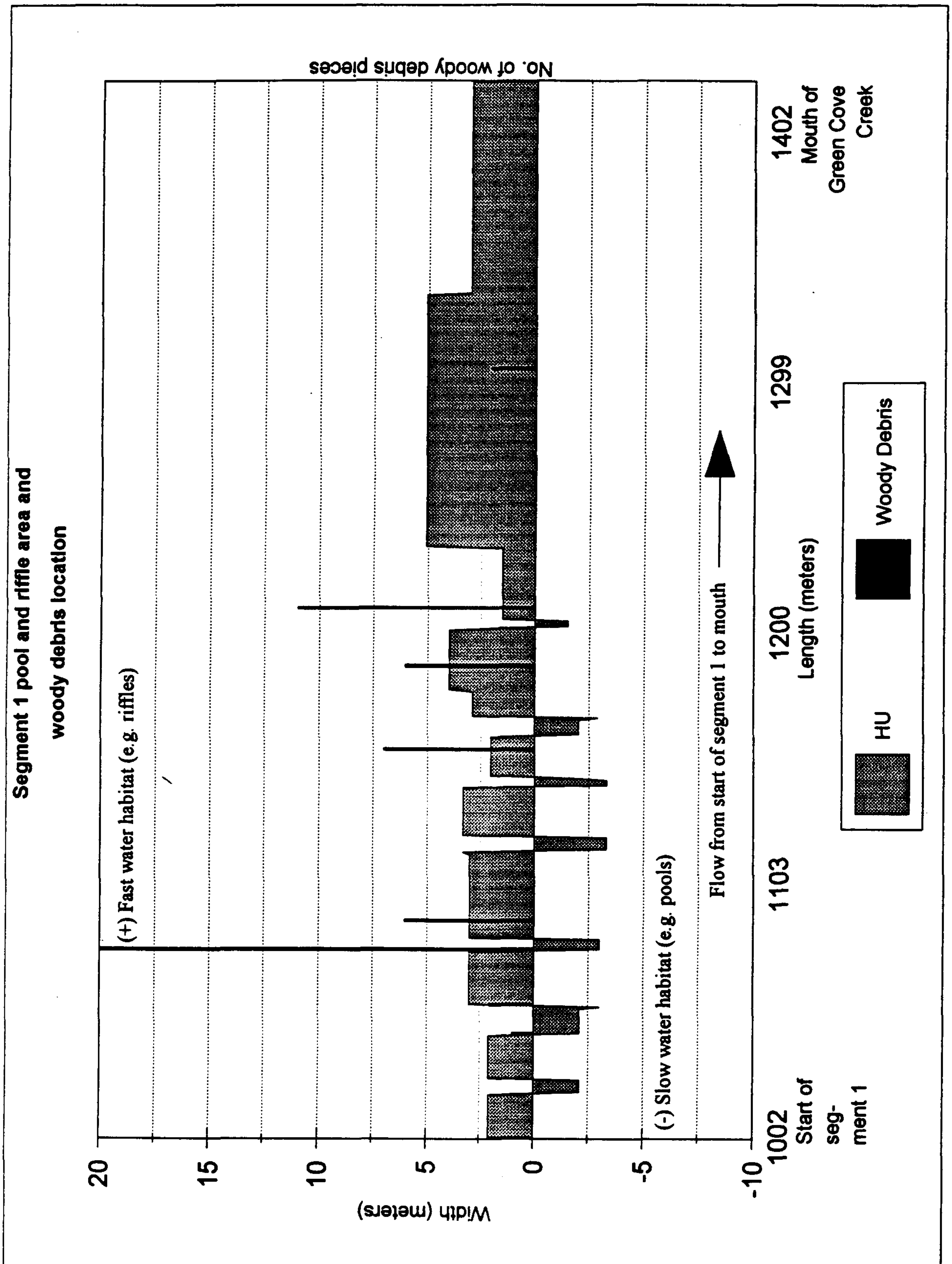


Figure 5-2 Green Cove Creek Segment 1 channel profile

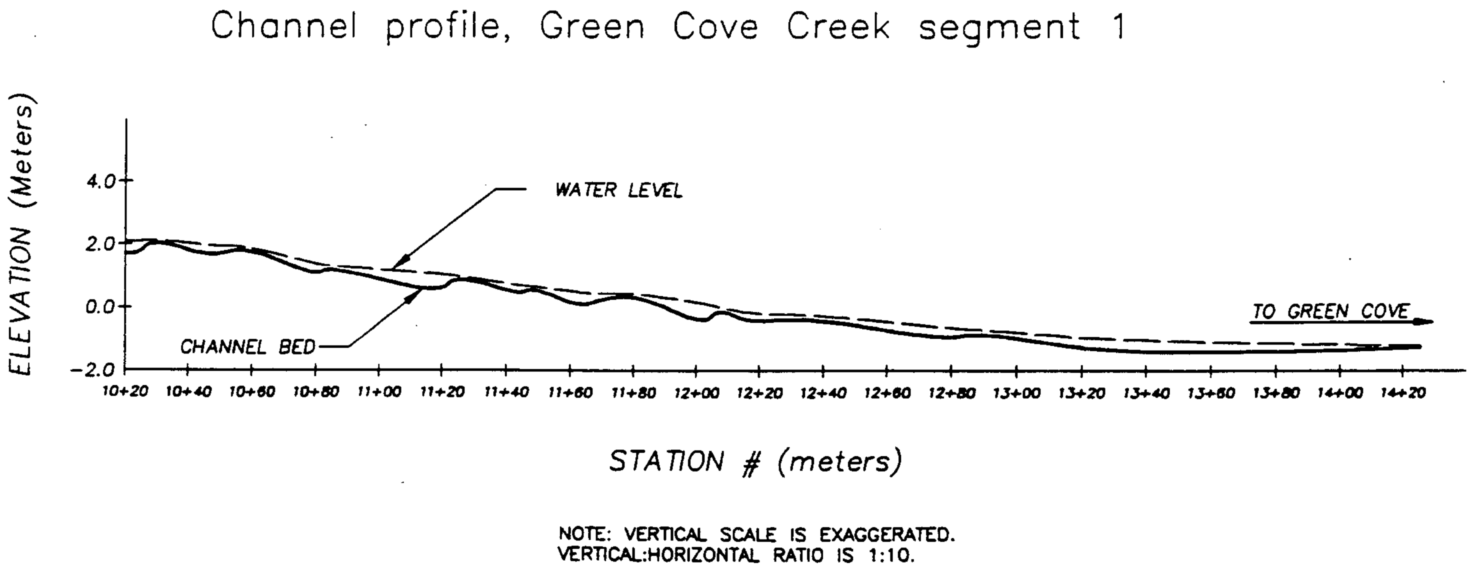


Table 5-1: Segment 1 habitat summary

Stream Segment Characteristics

Stream gradient:	0.3%	Confinement:	U	Sinuosity:	1.08	Stream order:	2
Avg bankful width:	28.30	Avg wetted width:	2.87	Avg wetted depth:	0.20	Width/:depth:	14.14
Segment length:	421.00	Upper elevation:	0	Lower elevation:	-1.19		

Resource Condition Indices Summary

Percent pools =	8.2%		rated as	poor
Pool frequency=	2.13	bankful widths per pool	rated as	fair
In-channel LWD pieces per bankful width=		4.50	rated as	good
Canopy closure=	20%		rated as	poor
Substrate=	fines		rated as	poor

Habitat Unit Summary Information

	Qty.	% Total	Total Area	% Total	Mean RPD (m)
Pools	7	31.8%	115.0	8.2%	0.33
Riffles	15	68.2%	1284.2	91.8%	Max. RPD (m)
TOTAL	22	100.0%	1399.1	100.0%	0.73
Res pools >0.3m deep:	1	Median Res pool depth:	0.52		

Segment 2 Habitat

Segment 2 is the longest segment of Green Cove Creek, and contains most of the fish habitat. The segment extends from above 36th Avenue NW down to the high tide line of Green Cove. Segment 2 is 2169 meters long, has a low-moderate average gradient of 1.5%, and is tightly to moderately confined within a forested valley that cuts down through the glacial material of the Cooper Point peninsula. The stream valley walls are low at the upstream end and increase in height downstream. The valley floor broadens somewhat at the upstream and downstream ends. The stream depth varies from deep plunge pools to shallow riffles, with a moderate width-to-depth ratio of 12.3.

Riffle-pool morphology characterizes segment 2. The stream has a moderately low sinuosity of 1.24, limited primarily by the confinement of the valley walls. Cobble-gravel point bars and occasional mid-channel bars have formed throughout the segment. The segment has a pool:riffle ratio of 41:59. Large woody debris pieces are the most important pool-forming mechanisms, but overhanging tree roots and occasional boulders also form pools and provide in-stream cover. Large, complex debris jams produce small cascades within the segment, and the gradient approaches 3-4% within short sections of the stream segment. Pools and riffles are evenly distributed throughout the segment.

Table 5-2: Segment 2 habitat summary

Stream Segment Characteristics

Stream gradient:	1.5%	Confinement:	C	Sinuosity:	1.24	Stream order:	2
Avg bankful width:	6.62	Avg wetted width:	2.78	Avg wetted depth:	0.23	Width/depth:	12.28
Segment length:	2169	Upper elevation:	33.13	Lower elevation:	0		
Length less culverts:		2070.01					

Resource Condition Indices Summary

Percent pools =	41.0%		rated as	fair
Pool frequency=	3.60	bankful widths per pool	rated as	fair
In-channel LWD pieces per bankful width=		1.63	rated as	fair
Canopy closure=	90%		rated as	good
Substrate=	cobble/gravel		rated as	good

Habitat Unit Summary Information

	Qty.	% Total	Total Area	% Total	Mean RPD (m)
Pools	91	38.4%	2349.2	41.0%	0.33
Riffles	146	61.6%	3386.3	59.0%	Max. RPD (m)
TOTAL	237	100.0%	5735.5	100.0%	1.08
Res pools >0.3m deep:	46	Median Res pool depth:	0.69		

Figure 5-3a through 5-3c depict the distribution of pools, riffles and woody debris through the segment. The figures demonstrate the interaction between large woody debris and pool formation. Large pools are found in close proximity to large woody debris complexes throughout the segment; for example, in figure 5-3a, large pools at 950 meters, 1055 meters and 1100 meters correspond with the location of significant debris jams. Figure 5-4 shows the changes in channel bed profile between pools and riffles.

Level or slightly rolling, well-vegetated flood plains about 10-20 meters wide cover the valley floor. Mature western red cedar dominates the riparian tree canopy, with bigleaf maple and red alder mixed in. Canopy closure through the segment averages 90%. The riparian understory vegetation consists primarily of salmonberry, lady fern, and vine maple, giving way to sword fern on the higher areas. Stinging nettles and piggyback plant are also widespread. Skunk cabbage occurs frequently on the low muck soils alongside the creek.

Slightly higher forested terraces occur in the wide areas where side ravines meet the valley floor. Black cottonwood, bigleaf maple and western red cedar dominate the canopy on these terraced areas, with a sword fern and salal understory. The valley walls are forested with a mature canopy of western red cedar, bigleaf maple and red alder. The slopes are well-vegetated with native understory species and appear stable in most locations.

Houses are visible occasionally on the level ground above the stream ravine, but only two houses are located within the valley itself. Riparian vegetation has been replaced with landscaped lawn at one site in segment 2A.

The stream channel in segment 2 runs through a dense glacial till formation characterized by the *Soil Survey of Thurston County, Washington* (US Department of Agriculture 1990) as Dystric Xerochrepts. According to the soil survey, "no single profile is typical of these soils" but the soil tends to consist of very gravelly sandy loam underlain with compact glacial till to a depth of 60" or greater.

The till layer is clearly evident throughout segment 2. At the upstream end, the stream runs over and through the upper till layer, consisting of dense, highly cemented clay with gravel and cobbles. The channel cuts down through the formation, exposing more banks of compacted till with high levels of unsorted gravel and cobbles. Undercut low banks with exposed gravelly soil and overhanging roots are evident throughout the segment.

The substrate of segment 2 consists mainly of cobble and gravel, with some fine sediment. Fine sediment levels in the gravel substrate are fairly low, but deposits of fine sediments occur frequently on the low banks and in the eddies. Ground water discharges from the valley walls at numerous locations, and is especially prominent emanating from between the soil layers in exposed banks. Slope failures are not

Figure 5-3A Segment 2A Green Cove Creek pool, riffle and woody debris distribution

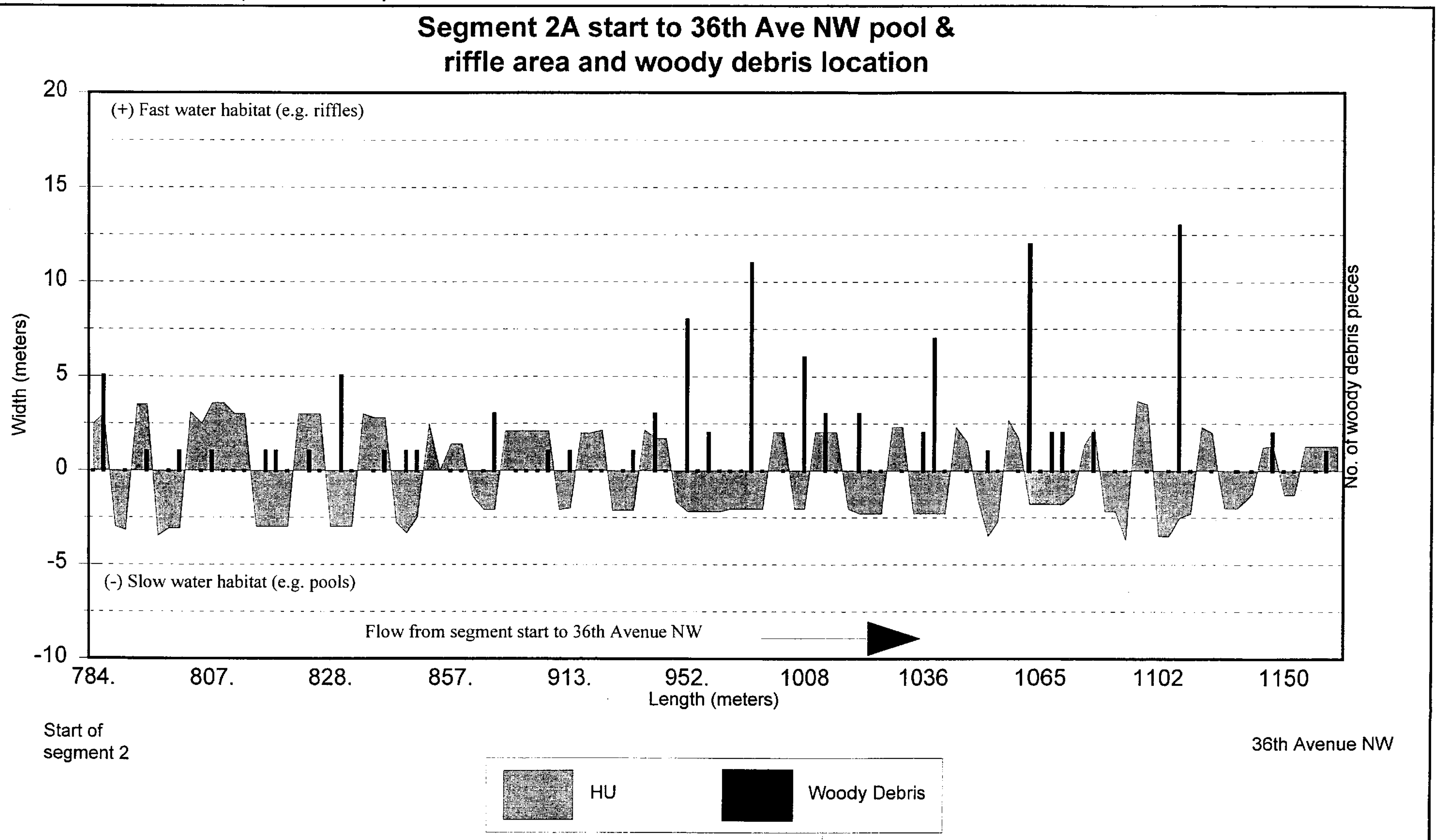


Figure 5-3B Segment 2B Green Cove Creek pool, riffle and woody debris distribution

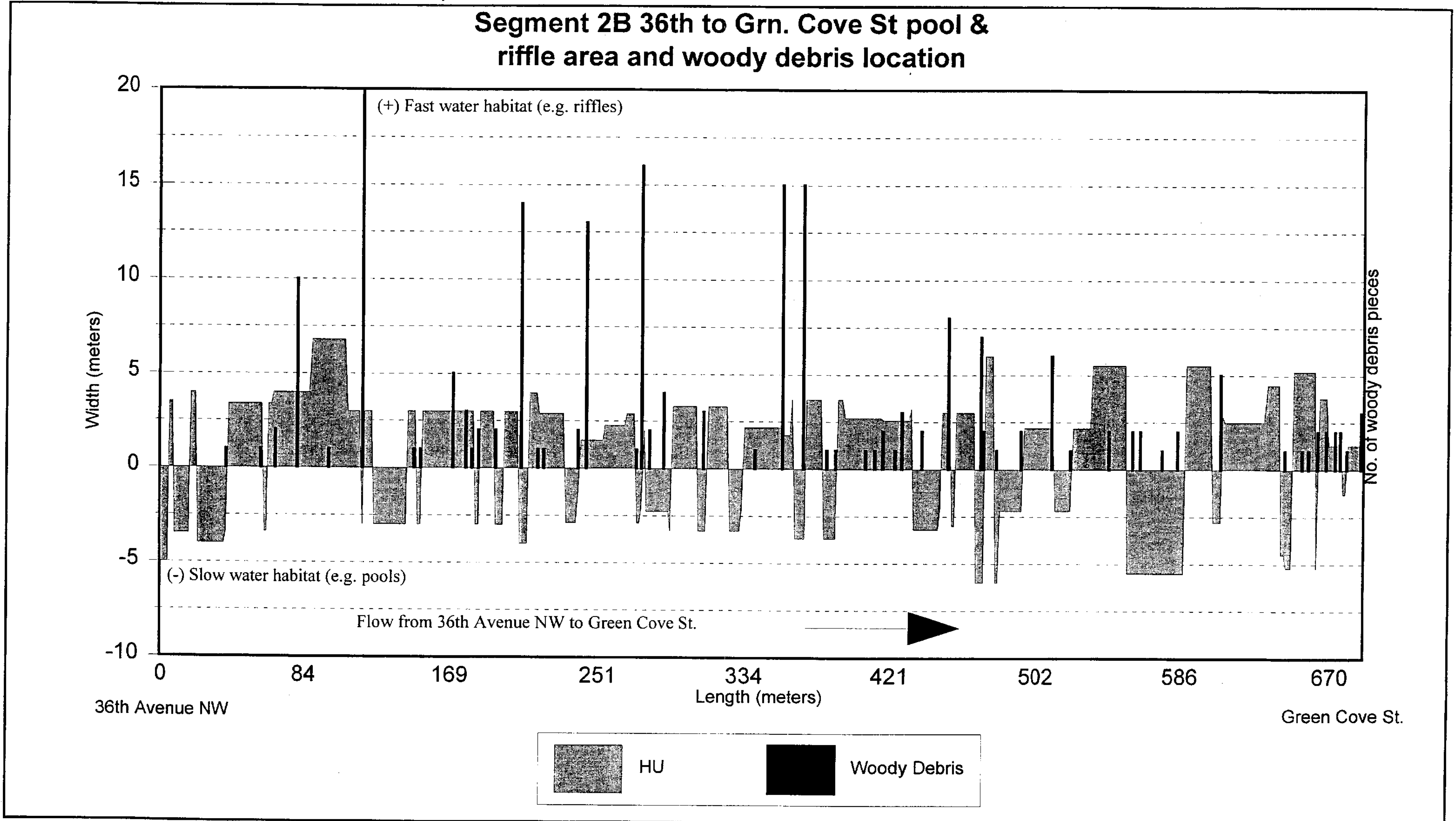


Figure 5-3C Segment 2C Green Cove Creek pool, riffle and woody debris distribution

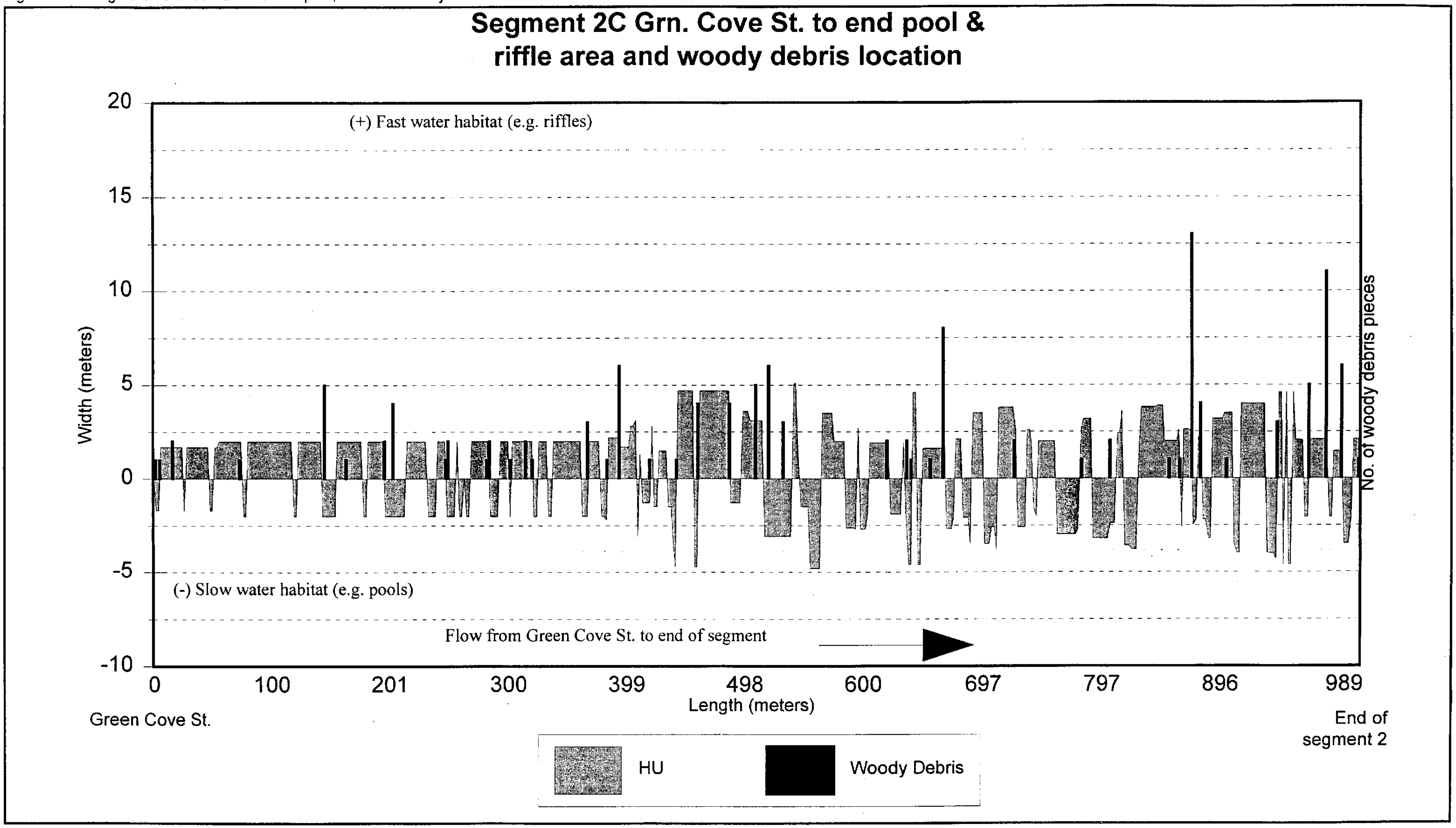
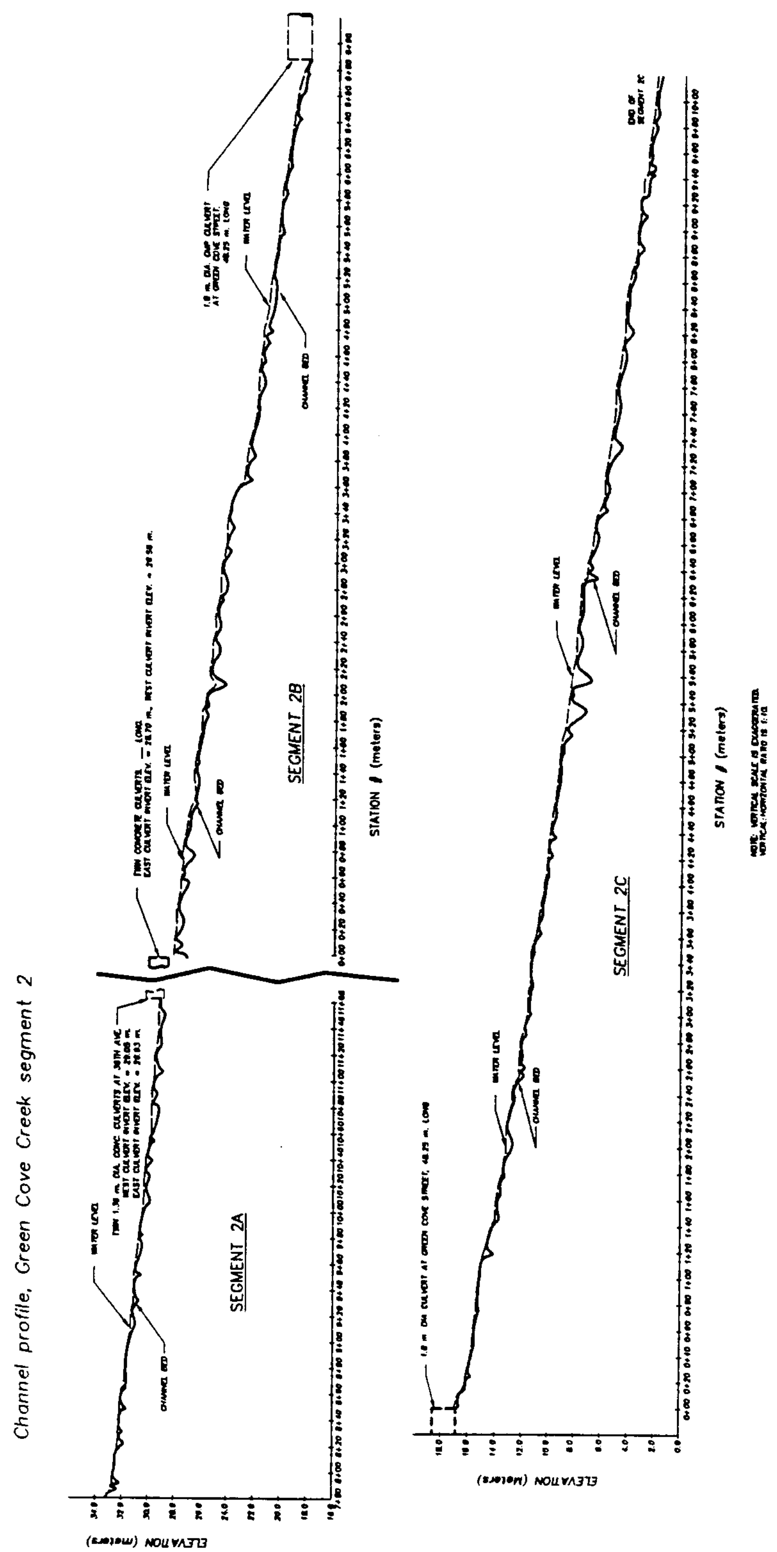


Figure 5-4 Green Cove Creek Segment 2 channel profile



widespread, but six seep-triggered slides were found. Two seep-triggered slides deliver sediment directly to the stream.

Stormwater discharge from Green Cove Street caused a large slope failure in a side ravine on the left bank, at about station 4+30 of segment 2C. The toe of the slide sits well back from the stream channel and does not deliver sediment directly into the stream. The outfall has since been extended down to a stable point lower in the ravine, but the existing slide has not revegetated and the surface continues to erode slowly into the creek. Also, the steep headwall scarp left by the original slide continues to fail periodically, depositing new material at the top of the slide.

Toe-undercutting of a vertical slope north of 36th Avenue causes a significant failure at about station 1+10 of segment 2B, on the left bank. The stream cuts away at the base of the slope, and large chunks of very gravelly compacted till topple into the channel. The stream erodes the chunks of till material and deposits coarse and fine sediment downstream.

Segment 3 Habitat

Segment 3 extends for 782 meters, from Evergreen Parkway almost to 36th Avenue NW. The segment has a low average gradient of 0.6%, and the segment is moderately confined in a forested area with level to gently rolling topography. The segment traverses a marshy wetland at the upper end. The stream depth averages 0.24 meters, with an overall moderate width-to-depth ratio of 10.7.

Glide-pool morphology characterizes segment 3. The segment has a moderate sinuosity of 1.4, but most of the meanders lie in the wetland at the upper end; several long, straight glides occur farther downstream. The segment has a pool:riffle ratio of 41:59. Debris jams, overhanging tree roots, and occasional boulders contribute to pool formation. Debris jams tend to be infrequently spaced through the segment. Glides dominate the segment, especially in the lower half; most of the pools occur in the slow, meandering upstream section.

Figure 5-5 depicts the distribution of pools, glides and woody debris through the segment. Small diameter, deciduous wood comprises a fairly high proportion of the woody debris in segment 3. Slow velocity and high sinuosity limit the stream's ability to move woody debris in the upper half of the segment, where most of the debris occurs. The long, straight glides below station 3+50 have retained little woody debris, except in a few large debris jams between station 4+00 and station 6+25. Figure 5-6 demonstrates the flat, uniform channel bed through the glide areas.

The riparian zone is broad and well vegetated throughout segment 3, and no buildings or cultivated lands occur within 50 meters of the stream. The riparian tree canopy in the segment alternates between sections of young red alder and bigleaf maple and sections of mature western red cedar. Overall canopy closure for the segment averages 65%.

Table 5-3: Segment 3 habitat summary

Stream Segment Characteristics

Stream gradient:	0.6%	Confinement:	M	Sinuosity:	1.40	Stream order:	2
Avg bankful width:	5.80	Avg wetted width:	2.52	Avg wetted depth:	0.24	Width/depth:	10.70
Segment length:	782.29	Upper elevation:	37.81	Lower elevation:	33.13		

Resource Condition Indices Summary

Percent pools =	41.4%			rated as	fair
Pool frequency=	6.74	bankful widths per pool		rated as	poor
In-channel LWD pieces per bankful width=			1.65	rated as	fair
Canopy closure=	65%			rated as	fair
Substrate=	fines			rated as	poor

Habitat Unit Summary Information

	Qty.	% Total	Total Area	% Total	Mean RPD (m)
Pools	20	34.5%	823.7	41.4%	0.34
Riffles	38	65.5%	1167.2	58.6%	Max. RPD (m)
TOTAL	58	100.0%	1990.9	100.0%	0.86
Res pools >0.3m deep:	11	Median Res pool depth:	0.58		

Young red alder and bigleaf maple dominate the canopy from station 0+00 to station 2+20, except for a mature cedar stand on the right bank from 0+00 to 1+50. Canopy closure averages 35% in this section. Reed canary grass dominates the understory in the swampy area above station 1+50, with salmonberry and lady fern from station 1+50 to 2+20.

Mature western red cedar dominates the tree canopy from station 2+20 to 4+30 and from 6+25 to the end at station 7+82, although bigleaf maple is an important constituent. The canopy closure in these sections averages 90%. Significant understory species include salmonberry, vine maple, lady fern, piggyback plant and stinging nettles. Sword fern dominates the upland understory.

The canopy between stations 4+30 and 6+25 consists of young red alder and bigleaf maple that supply little functional woody debris to the stream. The trees stand well back from the edge of the creek, and the canopy closure is only about 40%. Reed canary grass occurs in the understory throughout this section, with a significant infestation on the left bank from station 5+60 to 6+25.

Segment 3 runs through organic muck soil at the upstream end; then, from station 1+50 down, the segment flows over fine, densely compacted glacial till near the surface, comprised mainly of clay with little gravel or cobble. The stream has incised a channel into the till layer, which

Figure 5-5 Segment 3 Green Cove Creek pool, riffle and woody debris distribution

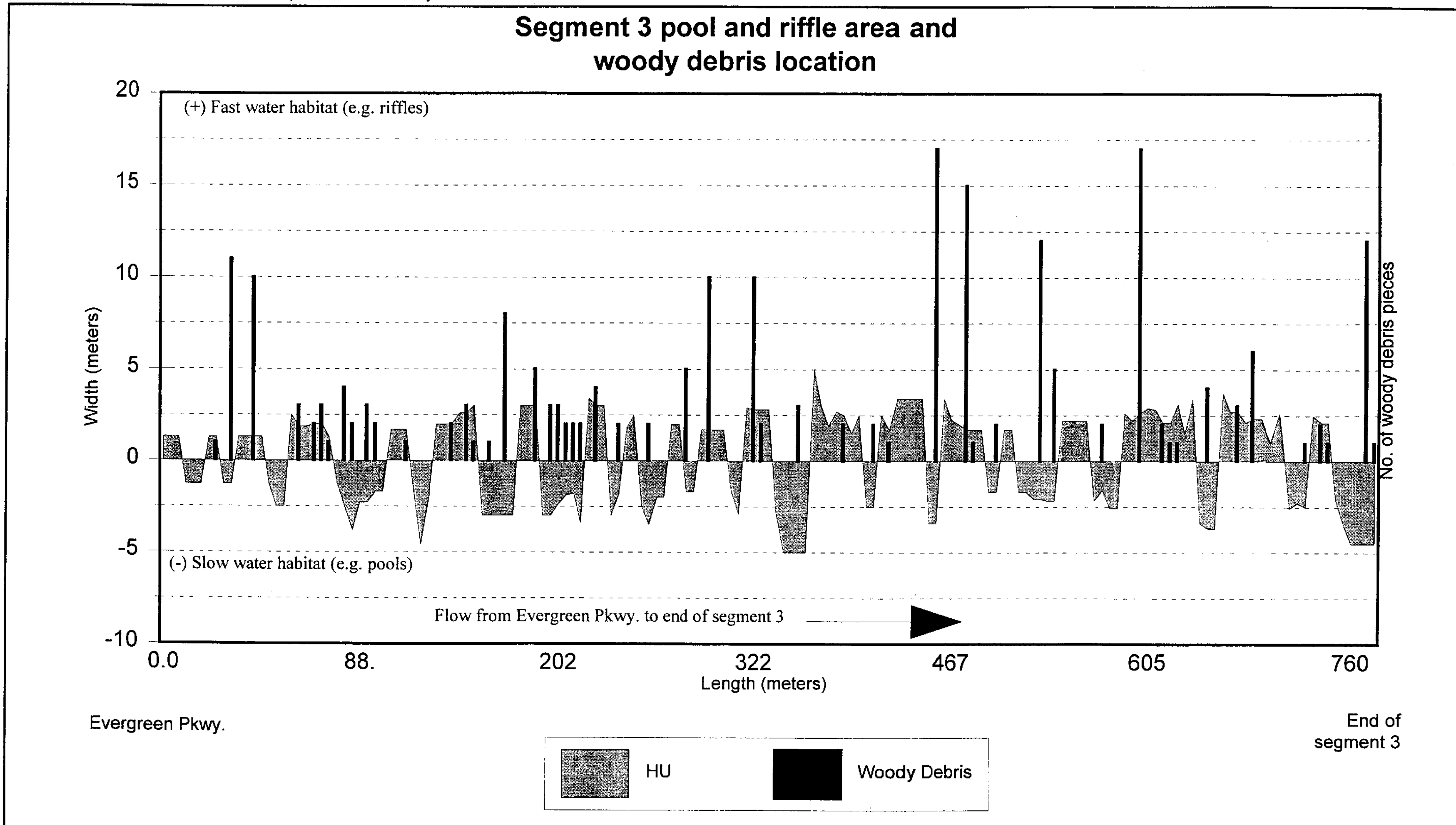
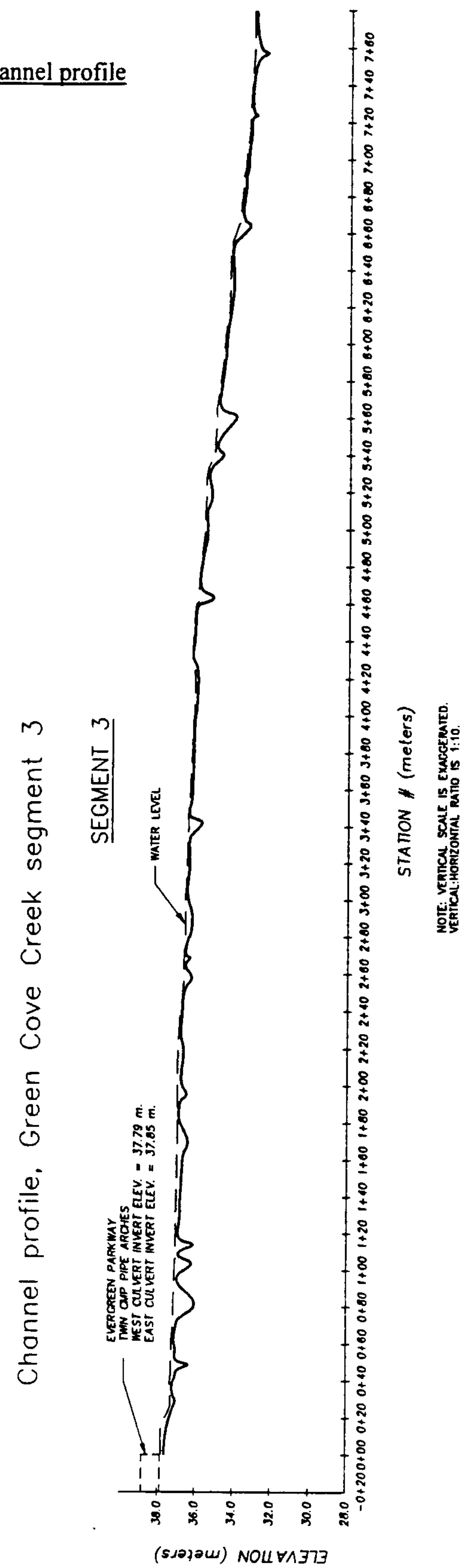


Figure 5-6 Green Cove Creek Segment 3 channel profile



confines the creek during most high flows despite the level topography. The low sinuosity and low width:depth ratio provide additional evidence that the stream is downcutting in this segment.

The substrate of segment 3 consists of hard, densely compacted clay with little gravel or cobbles, though boulders are scattered infrequently through the segment. The surface soil contains some gravel and cobble, but the incised channel prevents the stream from recruiting surface soil. The banks are low angle and stable, and pose no risk of land slide. Erosion is not significant, and is limited to a few undercut low banks. The Evergreen Parkway drainage outfall is the only stormwater discharge to the stream.

Fish Use and Distribution

Anadromous fish found in Green Cove Creek include chinook, chum and coho salmon, steelhead, and sea-run cutthroat trout. Resident species in the creek include, western brook lamprey, Olympic mud minnow and possibly eastern brook trout. Cottids and sticklebacks also probably occur (Fraser 1996). All observed anadromous fish species use the creek for spawning and rearing. Chum salmon spawn near the mouth and return to the sea after a brief rearing period. Coho remain in the creek and seek out wetlands and slow-water areas to rear for up to one year before migrating to salt water. Coho have been located at least as far upstream as the second culvert under Kaiser Road by the sewer lift station.

The Washington Department of Fish and Wildlife surveyed Green Cove Creek from the mouth to Evergreen Parkway for spawning coho 24 times during 13 years since 1974. Coho redds were located only once, although coho spawners were observed on all but 2 occasions. The surveys did not record the locations in the stream of the fish or redds, but interviews with staff and basin residents indicated that adult salmon rarely pass upstream of 36th Avenue. The department does not systematically survey Green Cove Creek because it is not an index stream for coho. Because the data is limited, the only supported conclusion is that coho do utilize the stream for spawning (Baranski 1991).

The Washington Department of Fish and Wildlife manages South Sound fish stocks at a hatchery harvest rate which may take more than 90% of the returning adult salmon, leaving few adults to spawn. The department mitigates for the high level of harvesting by supplementing wild fish stocks with hatchery-raised coho fingerlings, in order to utilize all the available coho rearing area despite low spawning rates (Baranski 1991).

The Department of Fish and Wildlife releases coho fingerlings to the creek at the outlet to Louise Lake. The number of coho released per year ranged from 12,200 to 56,336 between 1980 and 1995, the size of released fish ranged from very small (1,500/lb.) to rather large (210/lb.), and planting dates ranged from mid-February through early May (Baranski 1991; Kinney 1996). Recently, the department has planted 10,000-20,000 small coho fry each spring in Green Cove

Creek (personal communication with Jim Fraser, 1995). They remain in the creek until the following year.

Chum spawn in Green Cove Creek from late October through December. The Washington Department of Fish and Wildlife uses Green Cove Creek from the mouth to Evergreen Parkway as an index stream for chum salmon, but they have not surveyed the creek every year. Spawner surveys were conducted 35 times since 1974. The surveys found fairly low chum spawning levels; generally less than 50 per year. The surveys did not record the location of the fish. There are no records of chum plantings in Green Cove Creek.

Residents along the stream have reported seeing large numbers of spawning chum every fourth year (letter from J. Uehara, Department of Fisheries 1991; letter from C. Burns 1994). Large chum runs were reported every fourth year from 1971 through 1987 (no spawner survey was conducted in 1987, but a basin resident videotaped chum salmon in the creek). Moderate runs every two years following the large runs were reported to have declined since the 1970s.

According to the four year cycle, a large run should have occurred in 1991. Two surveys conducted in late December 1991 found fairly low spawner numbers. However, the 1992 survey recorded the largest run on record; 219 live chum and 215 dead chum were observed on five visits. Sixty-seven percent of the live fish were observed on the earliest survey (November 18). By December 8 the live count had declined to 10, and no live spawners were observed after that. Residents also reported a healthy chum run in 1996 (letter from C. Burns 1996).

A few plantings of game fish have occurred in the creek. The Washington Department of Fish and Wildlife planted 1000 eastern brook trout at the outlet to Grass Lake in 1981, 1000 coastal cutthroat at the same location in 1986, and 360 cutthroat in 1990 (O'Connor 1996). No game fish plantings have been reported since 1990, and it is likely that no eastern brook trout remain in the creek (Fraser 1996).

Results of 1996 Survey

Green Cove Creek experienced the highest flows on record in February 1996. The stream was inspected in April and May 1996 to evaluate the impacts of extreme peak flows. Maps from the 1995 habitat survey were taken in the field and compared to the conditions in 1996. New habitat unit measurements were not made, but all changes in location of debris jams and channel features were noted and new features such as erosion sites and sediment deposits were recorded. Random pebble counts were also conducted to verify the substrate characterizations, and canopy closure was measured.

Segment 1 appeared to have widened and deepened since 1995, and two debris jams had shifted. These were the only observed changes to the segment, which runs through tidal mudflats.

Three debris jams had shifted position or disappeared in segment 2C. Fine sediment had been deposited on the flat, vegetated banks that form the floodplain in the segment. Fine sediment deposits were found to a depth of 0.3 meters. There was little evidence of fine sediment within the wetted stream channel. Fresh gravel and cobbles had been deposited within the wetted channel in a few locations, primarily at the upstream end of existing mid-channel gravel bars and point bars in areas of moderate confinement.

Fresh low-bank erosion had occurred at several pre-existing erosion sites in segment 2C, primarily on the outer bends and near debris jams. No new land slides were found. Additional soil had toppled off the headwall scarp above an old debris flow where an outfall from Green Cove Street discharges to a side ravine at station 4+35 on the left bank. The debris flow remained unvegetated but did not deliver sediment to the stream. Subsequent surface runoff has delivered small amounts of fine sediment to the stream.

Increased mass wasting occurred at an existing seep-triggered slide on the left bank at station 3+70 of segment 2C. The slide activity broke through woody debris on the bank near the base of the slide and delivered fine sediment directly to the stream.

Two new woody debris jams had formed in segment 2B, and one large debris jam had shifted and grown significantly. Several other woody debris jams had shifted slightly. The stream had moved miscellaneous lumber and human debris from a site along the right bank near station 0+80, and distributed it for about 200 meters downstream. There was no apparent damage to the small footbridge at station 1+35 or the private bridge at station 3+15.

Several new gravel bars had formed along both sides of the channel and some existing gravel bars had grown in size, especially between station 1+10 and 3+15. All the new gravel in the stream appeared to originate from increased toppling of gravelly glacial till into the stream at the existing erosion site on the left bank at station 1+10. Large new fine sediment deposits occurred on the low, vegetated banks adjacent to the creek.

Two new seep-triggered slides had occurred on the valley walls in segment 2B, but neither slide delivered sediment to the stream. One existing seep-related slide on the left bank at station 2+85 had worsened and delivered some fine sediment to the creek.

One new debris jam had formed in segment 2A. All the existing debris jams were still there and appeared stable. There was little evidence of new erosion or deposition in segment 2A or 3, except for some slight erosion of overhanging low stream banks on outer meander bends.

5.2.3 Discussion

The salmon habitat in Green Cove Creek occurs upstream of segment 1, which is essentially a tidal mudflat. The discussion of habitat below excludes segment 1.

Coho Spawning Habitat

Coho in south Puget Sound typically spawn from late October to mid-December (SASSI 1992), and they prefer to spawn in smaller, gravel-bottom streams (Miller and Brannon 1981). Coho prefer to spawn in gravel substrate 1.5-12.7 cm diameter with less than 12% fines, in water at least 0.18 m deep, and with a temperature of 7.2-15.5 °C (Everest et al 1985; Watershed Analysis).

Coho in Green Cove Creek have access to 1791 meters of stream containing suitable spawning habitat in segment 2 below 36th Avenue. Spawning gravel is generally plentiful throughout the segment, particularly between 36th Avenue and Green Cove Street. Gravel and cobble of the appropriate size dominate the substrate, and fines range from 10-15%. The average water depth is 0.24 in summer and higher in winter, which is more than adequate for spawning. Water temperature was not measured during the spawning season, but maximum water temperature in the segment during the warmer summer months was approximately 15 °C, within the acceptable range.

The culvert at 36th Avenue blocked access to an additional 350 meters of stream with good quality spawning habitat. Gravel composition, water depth and temperature in this upper section (segment 2A) meet the requirements of coho spawners. Little or no spawning habitat occurred upstream of segment 2A, because the substrate composition changes to compacted fines and muck soil. A fish ladder was installed at this site during the summer of 1996.

The creek recruits spawning gravel primarily by undercutting the gravelly streambanks. Peak flows in the winter of 1995-96 recruited significant quantities of spawning gravel. The stream banks exhibited a natural level of undercutting with little loss of bank stability. The bank failure at station 1+10 appears to be an important source for gravel and cobbles in the channel substrate throughout segment 2B. The potential for future spawning gravel recruitment is high.

The stream does a good job of sorting out fines from spawning size gravels, due to even distribution of fast and slow water habitats through the system. Most of the fine sediment is transported downstream or deposited on the low banks and eddies. Vegetation and woody debris on the banks trap large quantities of fine sediment during over-bank flows.

Considering the high erodibility of steep glacial till, the valley walls are relatively stable, due to the compacted nature of the soil and the dense vegetation. However, the slopes are prone to erosion where surface runoff is directed onto steep areas, and where seeps cause saturated conditions. Several seep-triggered slumps occur throughout the segment, but most of them do not deliver sediment to the stream because they lie well back from the stream channel.

The major threats to spawning habitat are increased fine sediment inputs, loss of large woody debris, and loss of streamside vegetation. The upper basin wetlands retain sediment from the urban portion of the basin and keep it out of the creek. Surface erosion does not currently cause a fine sediment problem because only a few outfalls discharge to the surface of the erodible valley walls. Fairly abundant large woody debris and overhanging tree roots help trap fine sediment. Streamside vegetation stabilizes the banks and slows the over-bank flows, allowing fines to settle on the floodplains. Altering any of these factors could lead to degraded spawning habitat.

Coho Rearing Habitat

After they hatch, coho in south Puget Sound generally spend a year in their natal stream before migrating to salt water. Consequently, the number of fry produced by a stream tends to be limited by the year-round carrying capacity of the stream, rather than by spawning habitat (Miller and Brannon 1981). Pools are critical summer rearing habitat for coho, and coho production can be closely correlated with total pool volume (Nickleson and Reisenbichler 1977; Murphy et al 1984). Studies disagree on the importance of glides for coho rearing; some researchers have found that coho fry avoid glides (Bisson et al 1982) and others have found coho using glides and pools equally (Glova 1978; Murphy et al 1984).

Coho in Green Cove Creek have access to 1791 meters of rearing habitat in segment 2 below 36th Avenue. Upstream of 36th Avenue, segments 2A and 3 contain an additional 1132 meters of potential rearing habitat. The Johnson survey method indicated average percent pools for segments 2 and 3 of about 41%, rated fair according to the T-F-W criteria. Pool frequency was 3.44 channel widths per pool for segment 2, rated as fair, and 6.74 for segment 3, rated as poor.

Comparing the Johnson survey results to the T-F-W criteria indicated fair-to-poor rearing habitat. However, the T-F-W criteria were developed for use with the T-F-W survey method (which includes more detailed pool measurements). The T-F-W survey of segment 2 resulted in pool areas about 7% greater than demonstrated by the Johnson method. When the Johnson survey results are adjusted to account for this difference, the percent pool area approaches 50%. Also, a few long, low-gradient glides in segment 3 reduce the average pool frequency and percent area. The potential of glides for coho rearing is ambiguous; studies offer conflicting reports on coho utilization of glides.

Residual pools may give a better indication of summer rearing habitat on the creek. Residual pool depth averaged 0.33-0.34m for segments 2 and 3, which is above the 0.3m minimum depth preferred by juvenile coho (Everest et al 1985). Residual pools are distributed evenly through the creek system, including several large pools with depths approaching 1m. Approximately half of the residual pools were deeper than 0.3m, which is the minimum depth used by salmon in all flows (Johnson 1996). The segments with the sparsest residual pools also have the lowest gradients, where velocity is unlikely to cause problems for juvenile coho. During low flow conditions, juvenile coho exhibit a distinct preference for plunge pools and backwater pools

(Bisson et al 1982), which comprise most of the creek's pools. Overall, Green Cove Creek appears to contain fairly abundant, high quality summer rearing habitat.

Large woody debris from fallen trees created most of the pools in Green Cove Creek. The LWD in the creek is highly stable. The peak flows in February 1996 caused little shifting or loss of woody debris in the creek. The potential for continued LWD recruitment is high. The riparian tree cover consists of mostly mature conifers, with areas of mixed deciduous trees. Cedar and bigleaf maple, which have high pool-forming values, comprise most of the riparian forest. Alder, which has low pool-forming value due to its small size and rapid decay, comprises a low portion of the overall riparian cover.

The habitat survey did not measure winter rearing habitat. The pools in the creek offer good rearing habitat whenever base flow conditions occur throughout the year. The upper basin wetlands do a good job of retaining runoff and reducing damaging winter peak flows. Large woody debris and healthy riparian understory vegetation on the banks create slow-water refuges during winter high flows. Green Cove Creek contains an average of 1.63 pieces of LWD per channel width, rated as fair according to the T-F-W criteria.. The T-F-W criteria were developed for headwater streams, which typically contain mature or old-growth forest. Green Cove Creek contains high levels of LWD for a Puget lowlands stream. Riparian understory vegetation cover is high, with intact second-growth forest vegetation on almost all of the creek.

Southern Puget Sound coho seek out wetlands for winter rearing habitat during high flows (Cederholm 1992). Upper Green Cove Creek basin contains extensive wetlands that offers high quality winter rearing habitat for coho. Prior to 1996, the culvert at 36th Street prevented most downstream coho from reaching this prime habitat, but the new fish ladder should eliminate this obstacle. Also, some of the coho fingerlings released at the outlet of Louise Lake by the Department of Fish and Wildlife may remain in the upper segment and use the wetlands for winter habitat before out-migrating in the following year. Coho have been found as far upstream as the Kaiser Road lift station during electrofishing surveys (Fraser 1995).

The biggest threats to rearing habitat in Green Cove Creek are loss of large woody debris and increased peak flows. The creek currently contains adequate LWD and the riparian forest provides good long-term recruitment potential. The upper basin wetlands mitigate most winter peak flows in the creek, and the relative lack of stormwater discharges to the creek helps prevent peak flow increases. Altering either of these characteristics could lead to degraded rearing habitat.

Chum Habitat

Chum salmon enter the stream to spawn in late fall. They tend to spawn in the lower reaches of coastal streams, and can tolerate a wider range of substrate sizes than other salmon species. Chum fry in coastal streams move out to sea within a month of emergence (Miller and Brannon

1981). Chum spawning in Green Cove Creek has been documented only downstream of Green Cove Street.

The substrate in Green Cove Creek segment 2 below 36th Avenue provides good quality chum spawning habitat. The culvert at 36th Avenue probably has not limited chum spawning significantly because they prefer to spawn near the creek mouth. Winter flows and ponds are adequate for the brief rearing period that chum spend in the stream. Chum do not rear in the stream during the summer. The comments about coho spawning gravel recruitment in the preceding discussion also apply to chum spawning gravel.

Green Cove Creek Channel Stability

Channel stability is a function of channel geometry, soils, flow patterns and vegetation. The most significant flows for channel formation are the bankful flows, which are typically equal to the 1-2 year flows. In an undisturbed condition, streams typically reach an equilibrium that allows the stream to migrate within its floodplain, without causing significant widening or downcutting. Changes that can alter this equilibrium include increased peak flows, removal of streamside vegetation and removal of in-stream woody debris. David Rosgen has described a system of classifying streams according to their channel characteristics (Rosgen 1994).

The street crossings provide grade controls at three locations along the creek, and prevent it from downcutting at those locations. The channel appears to be fairly stable in segment 2, with little evidence of bank erosion. Segment 2 is classified as a B3-C3 channel according to the Rosgen system, which has a low-moderate sensitivity to disturbance (including increased streamflow magnitude) and excellent-good recovery potential. Vegetation plays a moderate to very high role in controlling the channel stability.

Segment 3 is classified as an F6 channel under the Rosgen system. An F6 channel has very high sensitivity to disturbance and fair recovery potential. Vegetation plays a moderate role in channel stability. These channels are typified by an entrenched meandering riffle-pool morphology on low gradient. They are laterally unstable, with high bank erosion rates. Segment 3 has the potential to contribute high levels of fine sediments to downstream gravels because the channel material consists of silt and clay.

5.3 GRASS LAKE WETLAND FISH AND FISH HABITAT

Grass Lake wetland was not surveyed for fish or fish habitat, but local volunteers conducted fish watches at a few sites around the wetlands. The fish observed by volunteers in Grass Lake wetland include Olympic mud minnow, yellow perch, stickleback, large mouth bass, bluegill and brown bullhead. Olympic mud minnows have been observed at several locations in Grass Lake wetlands, including the outlet to Louise Lake and the sewer line access road culvert (Upton 1995).

The Olympic mud minnow is found only within portions of the Olympic Peninsula and southwest Washington. Olympic mud minnows inhabit standing or slow-moving water in marshes and ponds with dense aquatic vegetation and at least several inches of soft fine silt with high organic content. They are believed to be highly sensitive to the substrate composition and water velocity. They are limited by the presence of predatory fish such as perch, and they do not occur in recently logged areas (Washington Department of Wildlife 1991).

Fish habitat in Grass Lake wetland is limited by the seasonality of open water. Migratory fish can rear in seasonal waters, but there is no evidence that migratory fish occur as far upstream as Grass Lake wetland. Resident fish require year-round open water, which is limited primarily to Louise Lake in Grass Lake wetland.

No coho or cutthroat were observed in Grass Lake wetland, despite annual coho plantings at the outlet, and occasional cutthroat planting. Coho would not be expected in the summer, when the water level drops and the wetland is not connected to the creek. However, coho remaining in the stream in late fall could be expected to use the wetland for refuge in the winter. No investigation was made to determine if coho use the wetlands downstream of Grass Lake wetland, in sub-basins GC50 and GC60.

5.4 CONCLUSIONS

1. Green Cove Creek contains good quality coho spawning habitat in segment 2.
2. The potential for continued good chum and coho spawning habitat conditions in the future is high.
3. Green Cove Creek contains good quality coho rearing habitat in segments 2 and 3.
4. In the past, the culvert at 36th Avenue prevented access to 350 meters of upstream spawning and rearing habitat, and additional rearing habitat in the extensive upstream wetlands; however, the new fish ladder should eliminate this obstacle.
5. Large woody debris recruited from the streamside forests plays a critical role in maintaining coho spawning and rearing habitat in the creek.
6. Stormwater discharges have not significantly degraded salmon habitat in the creek.
7. Increased peak flows could cause significant downcutting and lateral stream bank erosion in segment 3.
8. Upstream wetlands help reduce peak flows in Green Cove Creek.
9. There is inadequate information to evaluate the fish habitat conditions of the Grass Lake wetlands.