APPENDIX B
STREAMWALK SUMMARY

Dixon Creek
South Fork Squaw Creek
Lower Squaw Creek
Lower Sequoia Creek
Oak Creek

Watershed: DIXON CREEK

Date: November 1997

Location: West Tributary to North Fork

Observations: The small segment of creek most directly affected consists of approximately 300 feet of channel immediately upstream of Arrowood Circle just north of Sitka Place. The channel traverses set-aside open space (a community commons) within a suburban residential development in this headwaters area of the creek. Ownership is unknown. The channel is within a broad draw, has a generally very steep gradient, is 2-3 feet wide, 12-18 inches deep, and is intermittent.

The stream nearly disappears as a discrete watercourse in the upper part of the draw, especially where gradient locally flattens. Downstream, the channel becomes increasingly steep and more and more deeply entrenched as the road (Arrowood Circle) is approached. This results in exceptionally steep (>1:1) and essentially bare sideslopes which are many feet high. The terrain here at this lower end of the subject reach is man-made and surface soils appear to consist largely of sterile subsoils. These slopes at the lower end are therefore subject to chronic surface water erosion and are too steep and sterile to support ground-covering vegetation (without an exceptionally serious planting effort). The lower parts of the convex sideslopes here are too steep to ever support vegetation.

According to Patricia Benner, this area has incised and headcut to a considerable degree over the last several very wet winters and all appearances suggests that this is in fact the case. Channel degradation no doubt occurred because future channel adjustments accompanying alteration of the catchment's hydrology were not considered and planned for during site development. The trajectory (although not the rate) of channel adjustment in this area was perfectly predictable before development. That is, discharging more water into a high gradient channel traversing erodible material than the amount to which it was previously adjusted <u>will</u> result in channel degradation.

Apparently as a response to channel incision, a local property owner has lined the channel with angular rubble rock. Rock along the bank is now becoming stranded as the streambed degrades. The rock in the channel bed can only exacerbate a tendency for future lateral channel adjustments (i.e. widening). If left to its own devices, this segment of the creek will continue to be a chronic sediment source and, increasingly, an eyesore in this landscaped commons. This little stream unfortunately serves as an unequivocal and highly visible model of inappropriate channel management in the urban setting, especially in valuable open space areas.

Recommendations: Relatively minor channel bank regrading over most of the reach, a serious replanting effort, and the installation of appropriately placed, naturalistic grade control structures (otherwise known as channel-spanning sills, weirs or "check dams") would prevent further channel degradation and soil erosion in this area. Based on Todd's experience in these settings, large boulder sills tend to be simpler to build and more trouble-free than log sills. The very steep, deeply entrenched banks on the lowermost stream segment would need a low retaining wall structure integrated into the channel reconstruction. This could probably be either in the form of a hand-stacked stone treatment or a more naturalistic "boulder-strewn" bank.

All plantable surfaces should be amended with organic matter to improve the soil's tilth and

productivity. Attractive native species, many of which are used as landscape ornamentals anyway (e.g. vine maple, kinnickinnik, Oregon grape) can be planted in such a way as to preserve the view of this little creek channel for the neighbors. Mowing requirements would be reduced and people strolling the adjacent asphalt path would gain aesthetic and sensory benefits from the many small, noisy "waterfalls" now forming the watercourse.

Stewardship Opportunities: Most (and potentially all) of this project could be completed by community volunteers. The project scale is small enough and there would be no issues related to inwater work during the summer months. Small mobile landscape equipment, such as Bobcats, can potentially be operated by volunteers and can easily access the site without damage to property. Rock sills and retaining walls can be constructed with untrained manual labor (supervised) in this very small creek and of course volunteers could accomplish all the soil amendment and planting tasks. After a careful design is provided, the cost for equipment and supplies, including large stock plantings, is likely to be quite small (provisionally estimated at less than $7500.00).

Location: North Fork Dixon Creek, existing pond (Hidden Pond) immediately upstream of Walnut Boulevard.

Observations: Pond infilling with sediment; concrete outlet structure beginning to fail; potential source of thermal pollution (due to the large surface area of standing water and shallow depth) and chemical pollution (due to contamination by waterfowl excrement) to mainstem Dixon Creek; controlled water surface limits flood storage potential.

Recommendations: Remove the pond and outlet structure and re-create a naturalistic low-flow channel through the area. This would create a large in-line flood storage facility with considerable freeboard. The area would also sequester sediments (from continuing construction and/or poor management practices upstream) on the constructed floodplain. This could reduce sediment supply (and therefore channel-filling deposition) in the low-gradient, flood-prone area of Dixon Creek downstream. As an added measure, a sediment forebay and engineered channel cleanout area could potentially be installed on the upstream side of Walnut Boulevard. (Fish would not appear to be an issue because of the Walnut Boulevard culvert and very limited fish potential upstream.)

Location: Timberhill at Creek Tributary to Dixon Creek, Timber Hill Park immediately upstream of Walnut Boulevard.

Observations: Park appears under-utilized park at present; grass turf extends to channel margin; a major park activity appears to be dog walking, resulting in potential animal waste discharge to creek (no intervening buffer); moderate inchannel condition and poor riparian zone condition.

Recommendations: Regrade and replant the park (left) side of the creek to create a functional buffer; possible opportunity to retrofit (with extensive excavation) for meaningful flood storage, benefitting the flood-prone portion of Dixon Creek downstream. A sediment forebay and engineered channel cleanout could potentially be installed on the upstream side of Walnut Boulevard

in conjunction with this work. (Fish would not appear to be an issue because of the Walnut Boulevard culvert and very limited fish potential upstream.)

Location: Near Walnut Place

Observations: A residential structure (deck?) has been placed over the channel just downstream of the Walnut Place crossing. This represents undesirable infrastructure encroachment on the floodway and poses a hazard during floods. (The view of this structure was obscured by blackberry thickets.)

Location: Substation and Hoover School to Northwest Baptist Church Site

Observations: Stream is deeply to moderately entrenched and moderately confined by infrastructure, with significant areas of riparian open space. Cover is mainly either a rank growth of grasses or mowed lawn, with substantial areas of blackberry. The channel is deeply incised near the Hoover School and substation, with many mature alder trees rooted low along the channel. Erosion on the steepest banks here (1:1) are experiencing some erosion, exacerbated by the low-rooted trees, which act as hard points and locally concentrate scour. A sewer crossing in this vicinity has been uncovered by channel incision. The concrete cap over the pipe has been partly removed, leaving the pipe exposed.

Extensive and broad channel-marginal flood benches occur in the vicinity of Northwest Baptist Church, suggesting recent incision into an area of former alluviation. This area is maintained and mowed for recreational use. Overhead cover is generally good and is afforded mainly by alder.

Overall instream and riparian habitat quality is low throughout this entire reach. The overall trajectory of channel change in the area is stream degradation (channel incision and widening). This is evidenced by exhumed rooted tree trunks in the active channel, suspended outfalls, laterally undercut tree roots, bank failures, and toppling trees. This reach is now a chronic sediment source for Dixon Creek.

Recommendations: Regrade and replant streambanks and install naturalistic and fish passable channel grade control structures. A large area (+5 acres) of open space, which is likely used only seasonally, in the vicinity of the Baptist Church site affords an opportunity to retrofit for significant flood storage in this area. A passive flood storage facility could be designed which enhances natural features and recreational use of the area during the non-flood season. Constraint: Private ownership.

Toppling trees present potential debris jam and bank erosion sites since the trees are likely to fall during a flood. To eliminate this hazard, the trees at risk can be removed, leaving the rooted stumps in place. The exposed sewerline upstream should be stabilized by recaping and installing grade control structures and channel marginal treatments to prevent further channel incision or widening.

Location: Northwest Baptist Church to 29th Street

Observations: Stream is channelized, deeply to moderately entrenched, and highly confined by mainly residential development. Banks along the lower reach appear generally stable, with extensive blackberry and ivy cover. Narrow flood benches marginal to the low-flow channel are common. Overhead cover is good (mainly alder), although overall instream and riparian habitat quality is low. Substrate is largely gravel and soft bedrock, with silt-floored backwater pools. There is evidence of beaver activity in this area.

Recommendations: Closely-spaced mature alders form a significant channel pinch point not far upstream of 29th Street. To eliminate this hazard, the lower bank trees can be selectively removed, leaving the rooted stumps in place.

Location: 29th Street to 27th Street

Observations: Stream channelized, deeply entrenched, and highly confined by residential development. Significant sections of lower bank have been revetted with stacked demolition debris (broken up concrete pieces). Non-protected banks appear generally stable because of cohesive bank materials, although significant bare upper bank areas occur which are subject to chronic but apparently low levels of erosion by scour or surface wash. Overhead canopy coverage is moderate, although some of these trees are rooted along the low-flow channel, creating a potential conveyance issue. Overall instream and riparian habitat quality is low. Substrate is largely gravel and bedrock. Fish passage is hampered at the 29th Street box culverts.

There is a stacked log/timber pile revetment of creosoted logs along the outside bend approximately 100 feet downstream of 29th Street. (Creosote-treated logs are not considered appropriate for the small waterway environment.)

Recommendations: The timber pile revetment structure is presently being undercut by high stream flows and should be watched for future instability. Alternatively, the structure could be preemptively replaced to provide a more durable, environmentally-appropriate structure associated with upper bank riparian revegetation.

Location: 27th Street to Elmwood Drive

Observations: Stream channelized, deeply entrenched, and highly confined by residential development. Extensive lengths of channel-confining bank revetments are present, especially along the right bank. These include high walls of stacked timbers, salvaged concrete pieces or stone. Unprotected banks appear generally stable because of cohesive bank materials and dense vegetation (mainly weedy blackberry and ivy). Overhead canopy cover is generally good. Overall instream and riparian habitat quality is low. Substrate is sand, gravel, soft bedrock. Fish passage is hampered at the 27th box Street culverts.

The breached remnant of a concrete low-head dam was identified at approximately 100 feet downstream of the 27th Street crossing. This was causing accelerated bank erosion. The dam was removed by the City in 1998.

Location: Elmwood Drive to Circle Boulevard

Observations: Stream channelized, moderately to deeply entrenched, and moderately confined by residential development. Banks are largely unprotected by revetments, although as few homemade lower bank treatments are present. Streambank angles vary from very steep to relatively low, with the banks appearing to be generally stable because of cohesive composition and extensive vegetation cover (mainly blackberry and ivy). Grass-covered flood benches occur, with some of these forming significant undercut banks. Overhead canopy cover is moderately good considering the small channel size, although overall instream and riparian habitat quality is low. Substrate is silt/sand/gravel. Extensive gravel bars were noted in the upper part of this reach. The Elmwood Drive box culverts were partially clogged with sediment deposits in November of 1997.

Recommendations: A small concrete stop log structure just upstream of Circle Boulevard creates a pinch point for a potential debris jam. Damming the creek here is inappropriate and removing this structure will relieve this hazard.

Location: Circle Boulevard to Kings Boulevard (Jefferson Elementary School)

Observations: Stream is moderately entrenched with no confinement by developed infrastructure along the right (south) bank; a parking area closely encroaches on the north bank. The school property along the right bank appears to be under-utilized, consisting of the maintained playground most distant from the school buildings and a large, infrequently-mowed vacant area to the west of this. Relatively recent enhancement plantings have supplemented mature alders on the south bank, resulting canopy coverage of the channel which should impove over time. Low flood benches with undercut banks are extensive along this reach, producing overhead cover and somewhat improved aquatic habitat compared to many other reaches. Overall instream and riparian habitat conditions must still be considered degraded. The prevalence of these low flood benches creates a narrow two-stage flood cross-section, mimicking a natural floodplain where overbank areas absorb much of the energy of high stream flows. Substrate is silt/sand/gravel. Channel bank and beds appear essentially stable. The Circle Boulevard twin box culverts were partially blocked by sand and gravel deposits in November of 1997.

Recommendations: This large area of under-utilized, publicly-owned open space immediately adjacent to the stream provides a potentially valuable opportunity to create a relatively large passive flood storage facility. This can be a true multi-objective urban stream rehabilitation project, with habitat, recreational, and visual improvements readily integrated into the flood alleviation design. The standard prescription would be to excavate a large area adjacent to the channel to greatly enlarge functional floodplain area.

Stewardship Opportunities: Enhancement work here affords obvious educational/volunteer opportunities.

Location: Kings Boulevard to Beca Avenue

Observations: This area was enhanced for improved drainage in 1997. The work consisted mainly of streambank regrading to enlarge the flood conveyance cross section and the installation of bypass pipes at road crossings. Upper bank planting of native riparian trees will eventually provide overhead cover, improving the thermal regime of the creek.

Recommendations: The left (north) bank just downstream of Kings Boulevard began failing (due mainly to mass wasting processes, not fluvial erosion) in the winter of the 1997-98. This area was at the upstream end of (and primarily upstream of) the previously described streambank work. Watershed Applications analyzed the site and recommended a planted log cribwall treatment along this section of bank. This was installed by the City in the fall of 1998.

Location: Beca Avenue to Buchanan Avenue

Observations: Moderate entrenchment and moderate to low confinement by residential development. Banks through most of the reach are stable, although there are substantial areas of fresh bank erosion from recent floods. Bank cover angle varies from near-vertical (at failures) to quite shallow and bank cover varies from bare to grass to extensive areas of blackberry thicket. Glide and backwater pool habitat predominate (forced by riffles comprised of rubble and demolition debris or soft bedrock knickpoints). Substrate is primarily silt and sand. Overhead canopy cover is generally good, with this provided largely by ornamental plants and conifers. Overall instream and riparian habitat quality is low. Yard debris dumping along the channel margin is common.

Recommendations: On the left (east) bank upstream of Buchanan Avenue there is a large area of apparently under-utilized streamside property which could potentially be used to create an off-channel flood storage site. Constraint: Probable private ownership.

On the left bank just downstream of the junction of 15th Street and Lincoln Avenue there is bank erosion; grass to channel edge, and no native riparian buffer. A low dry stone retaining wall could be constructed along the bank toe. The upper bank could be regraded and planted with native riparian vegetation. Minor boulder grade controls could be installed to support the dry stone wall revetment.

Location: Buchanan Avenue to 11th Street (Corvallis High School)

Observations: Stream channelized, moderately entrenched, and moderately confined by school infrastructure. Banks are largely unrevetted, although there is a dumped rock riprap treatment at the bend just downstream of the Buchanan Avenue bridge. Localized bank failures are common and there is a partially slumped bank on the right channel margin about 200 feet downstream of

Buchanan Avenue. Downstream of this, an old outfall structure forms a hard point, with a small area of bank erosion immediately downstream. Tension cracks are common along the right bank just upstream of 11th Street. Bank vegetation is mainly weedy grasses and canopy cover is almost non-existent. Stream habitat in this low-gradient reach consists mainly of glide habitat formed by a backwater condition generated well downstream of 11th Street (see below). Fine-grained substrate predominates. Instream habitat and riparian zone conditions are uniformly poor. There was a large deposit of sediment under the Buchanan Avenue bridge in 1997.

Recommendations: Multi-objective rehabilitation project for bank stabilization, improved conveyance and bank storage, improved stream habitat, enhanced amenity value, and educational opportunities. This can be accomplished by regrading and replanting streambanks, creating a stable channel margin, and creation of a two-stage channel cross section (by the excavation of low, channel margin flood benches) in the long but relatively wide reach between opposing school buildings. Additional work could include adding a curb to the parking lot on the right bank and directing storm runoff through a stepped grassy swale instead of through the pipe now discharging directly to the creek. Enhancement work here affords obvious educational/volunteer opportunities.

Location: 11th Street to 10th Street

Observations: Stream channelized, moderately entrenched, and highly confined by residential development. Banks are largely non-revetted but appears relatively stable because of cohesive bank materials and blackberry and ivy vegetation cover. Overhead canopy coverage is good, with a large component supplied by non-native horticultural species (especially English laurel). Overall instream and riparian habitat quality is low. Substrate is largely silt. A 12-inch diameter steel pipe and rubble cover forms a low weir with a 1.5-foot drop about 125 feet downstream of 11th Avenue. This creates the long backwater extending upstream through the Corvallis High School reach. This weir/ramp also creates a long plunge pool below the structure. Sediment and vegetation-covered dumped riprap treatments up- and downstream of the 10th Street bridge restrict conveyance in this area.

Location: 10th Street to 9th Street

Observations: Stream channelized, deeply entrenched, and highly confined by both residential and commercial development. Banks are largely covered with a rank growth of non-native grasses or (especially) with dense blackberry thickets. Although banks appear to be mainly stable (because of cohesive bank materials and vegetative cover, the dense blackberry cover may be hiding bank failures: streambanks appear to be quite steep in these areas. Some of the turf-covered banks also appear to be deeply undercut and may be prone to localized failure. The left (outside) bank of the tight bend below 10th Street is revetted with dumped demolition debris and has an associated scour pool; the right (outside) bank of the tight bend upstream of 9th Street is turf-covered and is progressively failing as localized sloughs. Overhead canopy coverage is very poor and overall instream and riparian habitat quality is low. Substrate is unknown (most of the channel was inaccessible on the survey date) but is suspected to be dominated fine sediment accumulations because of low channel gradient: grade control at the 9th Street crossing creates a long backwater up through this reach.

Location: 9th Street to Reiman Avenue

Observations: Stream channelized, deeply entrenched, and highly confined by commercial development. The left bank is covered by a rank growth of non-native herbaceous weeds which appears to be periodically treated by cutting or herbicides. The slope angle here is about 2:1; the right bank is very steep (1:1) and covered with a similar but thin growth which appears to reflect poor soil conditions (gravelly silty clay). There are a few slump failures on this oversteepened right bank. Overhead canopy coverage is nil and overall instream and riparian habitat quality is extremely poor. Native herbaceous wetland species such as rushes and sedges (e.g. Scirpus sp.) occur along the channel bottom along with reed canarygrass and other weedy graminoids. The streambed consists mainly of gravel and rubble with vegetation-stabilized fine sediment deposits along the margins.

Recommendations: Regrade banks to lower angles (requiring widening of the easement and some removal of asphalt) or create low stone breast walls to allow lower angle plantable surfaces within the existing easement. Amend soils and replant banks (especially the south bank) with native riparian vegetation, including fast-growing species such as alders. Capture/treat parking lot runoff if feasible.

Location: Reiman Avenue to Railroad Tracks (end of survey)

Observations: Stream likely channelized but has begun to reinstate a sinuous alignment. The channel is deeply entrenched, however, and some relatively extensive bank failures have occurred here. Significant bank erosion is evident on the right bank just downstream of the Reiman Avenue crossing. This is both exacerbated by and evidenced by a poured concrete spillway draining a facility pad, which is now deeply undercut. The property is undeveloped so is presently mostly unconfined by infrastructure (especially on the right bank downstream of the light industrial facility (with the drain) near Reiman Avenue. The streambed varies from sand and gravel to coarse rubble, with shallow glide/pool habitat and intervening rubble riffles. Banks are steep but are widely separated, providing for a narrow but low, functional floodplain of both depositional and streamcut surfaces. Bank cover is largely non-native grasses with minor blackberry thickets and some native woody vegetation.

Recommendations: Variably regrade banks to lower angles to create plantable surfaces along the channel margin. Amend soils and replant banks (especially the south bank) with native riparian vegetation, including fast-growing species such as alders. Special emphasis should be given to preserving as much existing woody vegetation on the site as possible, including the large specimen oak at the top of the bank near the railroad tracks. Naturalistic grade control structures may be required, but these can also provide instream habitat and visual interest. rol and habitat. This project, in a site yet to be developed, could serve as a model for the preemptive rehabilitation of urban infill sites.

Watershed: SOUTH FORK SQUAW CREEK

Date: December 1997

Location: 500 Feet of Stream Corridor Immediately Upstream of 53rd Street

Observations: The City requested that this area be evaluated because it was slated for future development. The stream and floodplain in this area consists of a wide, continuous riparian corridor of ash and hawthorn trees with considerable channel-spanning downed woody debris (mostly smaller material). The channel is not incised and the floodplain is essentially unconstrained and hydrologically connected to the channel. There is no significant channel bed or bank erosion. There is a wide strip of ash woodland on the north side of the creek, with the likelihood that there are pockets of wetland in this area, although most of the floodplain area away from the channel does not appear to be jurisdictional wetland. These conditions make for a relatively diverse habitat area, with good restoration potential. Canopy coverage is good and riparian and instream habitat value can be described as moderate. Good channel/floodplain coupling suggest that much of the site is prone to flooding under high flow conditions.

Recommendations: As a condition for any development, require wide streamside buffer strips for the purpose of providing flood protection and wildlife habitat, in addition to the maintenance of channel shading.

Location: Straightened Reach Downstream of Technology Loop (600 Feet)

Observations: Stable but lacks visual interest and habitat value could be improved.

Recommendations: The wide set-aside buffer area between the creek and the multi-unit housing complex on the right bank affords the opportunity to enhance this area as a model for both habitat and visual improvement. The creek could be at least partially re-meandered through this reach at relatively low cost (minimal earth movement required because the channel is not entrenched). Existing volunteer woody vegetation could be supplemented with limited plantings (using volunteer regrowth in the rehabilitation strategy). Structural habitat for both terrestrial (riparian) and aquatic species could be improved with the addition of salvaged downed woody debris. Much of this work could be done at low cost by community volunteers.

Location: Sunset Park, North of the Existing Baseball Fields (1100 feet of channel distance, within a corridor width of 200-400 feet)

Observations: The channel is not incised and the floodplain is unconstrained through this large area, which includes significant amounts of native woody vegetation. Portions of the channel are lined with ash. The grassy swards and patches between woodland areas are presently mowed but these lawn areas provide no wildlife habitat. Nor do they provide an area for human use because of persistent wetness (much of this seasonally wet area appears to be jurisdictional wetland).

Recommendations: his substantial area of publicly-owned open space affords the opportunity to implement a large, multi-functional stream corridor rehabilitation project at relatively low cost. One way this could be done is by excavating multiple anastomosing (interconnecting) channels in the area. Relatively low cost is assured because the channel is not incised within its floodplain. In conjunction with grading, additional native riparian and wetland trees and shrubs, as well as large woody debris accumulations, could be installed throughout the area. This work could potentially occur over several years and be conducted by community volunteers. Ultimately, a low-impact boardwalk system could be routed through a portion of the renaturalized area. Such a treatment would provide 1) some level of flood storage (through both an increase in capacity and enhanced floodplain roughness), 2) water quality improvement by the filtering of overbank flows and shading in now sunny channel locations , 3) enhanced wildlife habitat, 4) enhanced amenity and passive recreational opportunities. (Note that these alterations may require an upgrade of the culverts under Country Club Place since the road crossing is quite low.)

Location: Country Club Place Downstream, South Side of Channel (500 feet of channel distance)

Observations: The lower part of this undeveloped area is quite wet (may be jurisdictional wetland) and the entire area appears to be abandoned pasture or hay meadow. The area is now growing into thickets of native rose and ash saplings with swards of buttercup and rush in the wettest areas. The area is now traversed by several small, fast-flowing drainage ditches, which appear to originate (at least in part) from the golf course uphill of Country Club Drive. Thus, untreated but potentially contaminated runoff is discharged directly to Squaw Creek.

Recommendations: Additional flood storage could be provided in this area by mass excavation. A low-cost alternate project would be to de-channelize at least the lower ends of the ditches, allowing the water to spread out over the toeslope wetland before reaching the creek. Constructing earthen, log or rock sills along the slope contour would enhance this effect. Water spreading in this area would provide water quality filtering of the golf course runoff before it reaches Squaw Creek. It would also provide a small (but incremental) amount of runoff detention, contributing to reduced flood peaks. This work could conceivably be accomplished entirely by manual labor at almost no cost (a good volunteer activity).

Location: Starker Arts Park Pond

Observations: High waterfowl use of this pond contaminates the water draining from the pond directly to the creek.

Recommendations: Convert the "100 foot long earthen ditch between the pond outlet and the creek into a broad vegetated bioswale with numerous log or rock sill drop structures.

Stewardship Opportunities: All of this work could potentially be accomplished by community volunteers.

Location: Downstream Of 35th Street at John Adams School (600 feet along the north side of the channel)

Observations: A considerable width of mowed grass in this streamside zone is apparently little used by the school because it is remote from school facilities and is persistently wet for most of the year.

Recommendations: Excavate a flood storage facility along the north side of Squaw Creek on John Adams School property. Re-meandering the straightened creek channel through this reach could be a part of this work but is not mandatory. Tree and shrub plantings would be used to create a riparian fringe to the off-channel flood storage area; wetland plantings could be installed within the facility. In addition to being already owned public open space, the site affords obvious educational/volunteer opportunities.

Complimentary work on the right (south) bank of the creek through this same reach could be accomplished on adjacent private property (church). Mowed grass on this property continues to the channel edge, which is over-steep and failing in places. There is sufficient space available to regrade the banks along the church property and install a functional woody riparian buffer here. At least one storm drain discharging from this property could potentially be daylighted and routed through a naturalized bioswale for stormwater pre-treatment. Constraint: Private ownership.

Location: Stream Corridor Several Hundred Feet Up- and Downstream of the Knollbrook Place Bridge.

Observations: Stream is not entrenched, generally only slightly incised (but becoming more incised at the downstream end), and only moderately confined by residential development (relatively wide setbacks). There is a narrow functional floodplain which is colonized by in its upper part by weedy grasses but is joined along the lower part by relatively extensive stands of hydrophytic forbs such as sedges and buttercup (Ranunculus). Canopy coverage is moderate (interrupted young stands of native riparian trees and shrubs along the south bank). Streambanks are silt/clay, with minimal bank erosion. Problem: Minor street flooding in this area.

Recommendations: Additional flood storage and improved habitat and aesthetic conditions could be provided in this area by relatively small-scale excavation to enlarge the floodplain area (accentuate the two-stage cross section). Machine access is good for this work. The opportunity for this especially good upstream of the bridge, and especially on the north side of the creek. Minor channel re-meandering could easily be incorporated within this work, at relatively low cost. Additional woody vegetation plantings, especially on the south bank, would improve canopy cover.

Watershed: LOWER SQUAW CREEK

Date: 1999

Location: Entrenched Meanders Downstream of Knollbrook Place

Observations: Squaw Creek begins to develop more sinuosity downstream of the channelized reach in the vicinity of Knollbrook Place. On the other hand, the straightened channel segment at Knollbrook Place at least possesses a partially functional floodplain while the stream become progressively more entrenched and de-coupled from its floodplain below this area. A private road servicing a few homes bordering the tight meanders of the creek on wooden bridges at two locations. This dead-end road extends west from Brooklane Drive. Bank erosion is occurring locally in the vicinity of these two bridges.

The channel in the area with a strongly meandering pattern is generally entrenched to a depth of 4-8 feet. Active channel width in this area averages about 10-12 feet, although there are some areas where the channel is narrower. Streambanks are generally very steep (often near vertical) but largely stable, being comprised primarily of clay. Very little woody debris occurs below the mean water surface elevation because the channel through most of this area has a chute-like aspect, with smooth clay banks. Most of the fine- to moderate-sized woody debris (including some larger logs) found within this reach is stranded on the flat above the channel and is well out of reach of ordinary stream flows. These woody materials provide no instream habitat whatsoever and thus the active channel itself exhibits low overall habitat complexity.

The streambed through this reach generally consists of clay, although demolition debris has fallen into the channel from homemade revetments and rubble rock has fallen into or been placed within the channel in places, such as around the bridges. Much of this very low-gradient reach consists of a long stretch of slackwater glide which is as much as 3-4 feet deep and in which flow is barely perceptible during low-water conditions. Some of this backwater is attributable to debris jams which partly block the channel. The roughly poured concrete apron around the westernmost private automobile bridge also forces a long backwater pool.

Much of the creek in this reach is bordered by dense blackberry thickets, although there is an overstory of larger ash, oak, maple and alder trees in the central part of the area. The understory here includes blackberry as well as a number of native shrubs, such as snowberry, serviceberry, oceanspray, hawthorn, Pacific ninebark and hazel.

Willow is locally abundant along the uppermost part of this reach. In this area, willow branches extend well below the top of bank. Minor floated debris accumulations were found throughout this reach when evaluated in August of 1999. This is partly because the willow branches tend to capture flood-borne debris.

There was a prominent debris accumulation which fully spanned the channel in the vicinity of the Reed Place cul-de-sac. Fish passage through this area under low-flow conditions was impossible. The dam was formed from sediment, demolition rubble, and fine to coarse woody debris and has apparently persisted for some time because it had a willow sapling rooted in it. The top of the dam was about 2 feet above streambed grade. This deposit not only fragments aquatic habitat but is

causing accelerated bank erosion in its vicinity. In a few other areas, large root structures also pinch down and entirely block the low-flow channel.

Along healthy, un-incised streams, such low slung branches generally provide healthy riparian habitat. In contrast, neither the branches or their accumulated debris was within the ordinarily flooded portion of the channel cross section within this entrenched channel. In a few places, some moderately-sized branches and racked-up wood pieces nearly penetrate the water surface but these provide only minimal instream cover. Because of the stream's entrenched condition, this material also tends to cause local channel erosion. Successive accumulations such as this may contribute to local backwater flooding in the vicinity of Knollbrook Place.

One apparently private water pump was also noted on this reach of Squaw Creek. The pump appeared operational and is probably used for domestic irrigation. Many such private pumps on small urban streams are not a permitted use.

Recommendations: Minor pruning of the overhanging willow branches along a portion of this reach could reduce the tendency for debris jams to occur here and perhaps alleviating flood impacts somewhat in the residential area upstream. Selective pruning of only the lowest branches would not impact habitat conditions because their removal will not affect channel shading or damage the plants. Very little of the debris hung up on these branches extends into the ordinarily wetted channel perimeter but is instead left suspended above the wetted channel after flood recession. This captured debris (and the living branches that cause this) do not provide instream structural habitat because the debris is mostly fairly fine and perishable, because it is transient (passing through during floods), and because even the larger wood pieces are only rarely in the water.

More permanent flood relief in the Knollbrook area might be achieved with some sort of high flow bypass through this area. Because stream gradient is low in this area, the resistance to flow imparted by the meander bends must form some component of the flooding in areas upstream. Such a high-flow bypass channel would not effect ordinary flows and could be enhanced as a habitat area within the riparian zone.

Location: Confluence with Marys River Through Channelized Reach

Observations: The confluence of Squaw Creek with the Mary's River at Brooklane Drive is impassable to fish in the absence of very high Mary's River flows backwatering up into this area. There is a ±4 foot high concrete weir with a vertical face and no plunge pool (just angular boulders) immediately downstream of the Brookland Drive bridge and flow goes subsurface in the steep, rock-filled channel from the weir downstream.

Squaw Creek makes a sharp turn immediately upstream of the bridge. This bend is fully revetted with quarried rock rip rap. The stream has a nearly straight alignment for hundreds of feet upstream of this bend, having been channelized at some point in the past. This straightened and re-aligned reach still retains a generally trapezoidal cross section and is entrenched about 8-12 feet below the surrounding terrain. Channel gradient is low and streambanks appear to consist mainly of silty clay, making them relatively resistant to erosion.

Confinement due to entrenchment as well as episodes of sediment deposition within this reach has resulted in the formation of sporadic low flood benches only a few feet wide within this reach. This provides some incipient sinuosity to the low-flow channel in this otherwise straight channel segment. The low flood benches are stabilized by alien grasses (especially reed canarygrass) and mainly weedy forbs, such as creeping buttercup. Active channel width is about 10-12 feet but the low-flow channel is often considerably narrower than this because of the accreted benches. Where the channel bottom could be observed, it consisted of basalt boulders and rubble with heavy silt deposits. This suggests that the channel was lined with rock when it was constructed.

The bank slopes above the low-flow channel are at an angle of 1:1 or somewhat shallower and support mainly dense blackberry thickets which are penetrated here and there by relatively immature individuals of native woody riparian species, including alder, ash, oak, maple and willow. However, these plants grow densely enough and are mature enough to provide moderately good shade to the channel, except in the reed canarygrass-dominated section just upstream of Brooklane Drive.

Floated tree limbs and medium-size woody debris, along with a few small logs, form occasional accumulations within this channelized reach, caught up in the limbs of brushy vegetation growing along the lower banks. These cause local bank erosion within this confined channel while at the same time providing some insteram habitat diversity. The presence of the flood benches also creates a deeper low-flow water column than would have been present just after channelization, thereby improving both stream temperature conditions and instream habitat. Nevertheless, channel habitat conditions must still be regarded as degraded, with poor opportunities for fish to hold in this reach during higher stream flows.

The general habitat conditions described above continue up through the broad bend and subsequent short straight reach just below the "outlet" of the entrenched meanders (see below). However, tree growth becomes more mature in the upstream area (creating a more "tunnel-like", shaded channel). The left (outside) bank in this area has been revetted with dumped rock and concrete demolition debris. A channel-spanning debris dam was located in August of 1999 in this area (about 250 feet downstream of the easternmost private automobile bridge; see below). The deposit consisted of both sediment and small to medium-sized woody debris and formed a fish impassable barrier at this location. This deposit apparently resulted from the accumulation of flood-borne debris on a very low, sweeping willow trunk which partly blocks the channel here. The dam stood about 4 feet high above streambed grade.

Recommendations: In terms of immediate priority, the small debris jam just discussed should be removed unless higher seasonal streamflows have already done this. However, the structure appeared stout enough that it may persist through the high-flow period.

The entire designated reach down to the Brooklane Drive bridge is essentially free of encroaching infrastructure, making functional restoration in this area technically straightforward. The undeveloped stream corridor width through this reach is generally on the order of several hundred feet. This would allow extensive bank slope reprofiling and functional floodplain re-creation along with stream re-meandering. Structural habitat improvements for instream cover could readily be built into the channel at this time. However, upstream development suggests fine sediment delivery would remain an issue in this reach insofar as instream habitat conditions are concerned.

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A more restrained channel rehabilitation approach is also possible in this reach. This might entail removing the blackberry thickets, lowering bank angle to some degree (but preserving the native woody vegetation wherever feasible), accentuating the "apparent" sinuosity of the stream by widening the existing flood benches in a staggered pattern from bank to bank (while preserving a narrow low-flow channel), and replanting native tree and shrub vegetation along the upper bank slope. This could create a well-shaded but more open creek corridor in this reach. Structural habitat improvements to the low-flow channel could also be installed as a part of this more restrained approach.

of these properties could be appropriated without completely eliminating the backyards, assuming the residents are willing participants.

Wherever feasible, Todd suggests regrading bank slopes to a lower angle than was possible on Dixon Creek. This should increase groundcover and tree planting success and minimize the risk of localized slope failures in the future. A number of the properties, especially those which front on Sycamore Avenue, have very deep backyards so this may be feasible in much of the area.

It would be useful to maintain or construct a narrow low-flow channel (3-4 ft wide or so) to assist in temperature modulation and the improvement of (at least seasonally-available) aquatic habitat. This can be done by preserving existing depositional flood benches, and creating new flood benches when cutting back the banks, as was done on Dixon Creek. As an optional treatment, in areas where the channel currently has a wide, "flat" floor, low channel-pinching benches could be constructed by creating a stable perimeter of large rock or coconut fiber logs, backfilling these structures, then stabilizing these surfaces with seed and matting, or with pre-grown turves (sod mats). Areas of excess fine sediment accumulation, such as upstream of small debris jams and in the vicinity of the major pipe outlet near Trinity Missionary Church, should be cleaned out as part of the channel rehabilitation work.

If there is interest in it, bank regrading and (possible) low-flow channel reconstruction could be conducted in a manner that disguises the straightness of the channel. Making the new bank slope contours sinuous, and shifting the low-flow channel from side to side with flood benches (constructed or preserved), would impart a more natural appearance to the channel. This would improve the aesthetics of this reach considerably. On the other hand, there may be no need for this extra effort since it is not a public access area.

Beneficial trees growing along the upper portion of the bank (south bank in particular) might be retained wherever feasible so as to not completely eliminate the shade canopy from the creek corridor. Hand-stacked stone retaining walls or riprap can be placed adjacent to preserved trees where slopes cannot be laid back if this option is chosen. Todd has applied this technique with success on several projects.

As recommended for Dixon Creek, aggressive tree planting should be applied to upper regraded bank slopes and the top of bank, leaving the lower bank open for conveyance purposes. Trees should be preferentially planted on the south bank if budget is limited. Recommended species include, but are not necessarily limited to, alder, Oregon ash, bigleaf maple and white oak. Cottonwood seedlings and saplings growing within the low-flow channel should be eliminated as they will eventually interfere with flow conveyance.

Finally, it might be useful to construct sediment traps or forebays where major pipes outlet to the open channel of Sequoia Creek (i.e. Highland Drive and the major left bank outlet situated just downstream from Fairlawn Street). These could be constructed for periodic easy cleanout by heavy machinery.

Stewardship Opportunities: Tree planting and maintenance to insure successful plant establishment.

Watershed: LOWER SEQUOIA CREEK

Date: April 28 and 29, 1998

Location: Highland Drive to 9th Street

Observations: This segment of Sequoia Creek in the Corvallis lowlands is completely channelized and undoubtedly bears little relationship to the original Sequoia Creek drainageway. The channel appears as a straightline ditch which is formed in cohesive silt/clay material, is entrenched about 6-8 feet below the regional grade, and has a very low gradient. Low-flow channel width varies from about 3 feet (where low depositional flood benches are present) to 12 feet. The streambed consists of silt or fine sandy sediment, with occasional very loose, deep deposits of this material. There are also occasional channel-blocking accumulations of man-made debris (tires, lumber, etc.) and smaller woody debris in the low-flow channel. Banks are generally stable and in most places are covered with weedy grasses or forbs, or blackberry thickets. The woody vegetation canopy is interrupted in places but trees or shrubs generally occur on at least one bank over most of the length of the corridor. Trees and large shrubs range from seedlings to mature individuals of cottonwood, willow, alder, hawthorn, *Prunus* sp. (e.g., cherry) and occasional ornamentals such as exotic conifers.

At Bruce Moser's request, Todd looked for a pipe outfall on the left (north) bank which appears on City maps generally in line with Fairlawn Street. Todd was unable to locate this outfall because the bank in this vicinity was covered with a blackberry thicket. However, there was no obvious evidence of a functional outfall in this vicinity, such as a locally eroded bank.

A major pipe feeds into Sequoia Creek on the left bank about 150 feet east of Fairlawn Street (and just west of the Trinity Missionary Church). The outlet consists of a broad concrete arch, the roof of which is about 4-½ feet above the streambed, which consists of silt and fine sand. Channel invert width is about 15 feet. The homeowner immediately upstream reports that small children walk along the top of this outlet structure, which is crossed by a fence (leaving only a narrow edge on which to walk). He is concerned for their safety. The hinged steel grate gate on the structure was found open during the April 28 field visit.

Because the stream is extensively piped upstream of this area, and because it goes dry in the summer, it is our opinion that instream habitat conditions (which are very poor) should not greatly influence channel management decisions with respect to flood relief on this segment of the creek. Todd's discussion with Gary Galovich of the Oregon Department of Fish and Wildlife (and a member of the SWPC) back in early March suggested that the ODFW would likely concur that this system has low rehabilitation potential with respect to fishes, especially salmonids.

The City has indicated that this segment of the creek is extremely flood prone and they would like to see some rehabilitation work done here this year. We agree and believe that the stream corridor environment in this reach can be benefitted by an appropriate flood improvement project in this area.

Recommendations: The obvious approach to improving flood conveyance here is to enlarge the floodway cross section, as was done last year on Dixon Creek. The stream corridor is closely encroached upon by backyard fences, leaving an "average" corridor width on the order of 30-40 feet. However, the backyards of the residences along the creek are generally fairly deep so a segment

Location: 9th Street to Highway 99W

Observations: A large quantity of fine sediment has accumulated in the three box culverts under 9th Street. The straight reach between 9th Street and Highway 99W is hemmed in by commercial parking lots and has a highly simplified cross section with a 12-foot wide silt-floored streambed and steep (~1:1) bank slopes. There is no hindrance to conveyance through this reach but curb-to-curb stream corridor width is only about 30 feet. Moreover, flow conveyance is retarded by the sharp left bend taken by the channel when it reaches the vicinity of Highway 99W as well as by the double channel configuration (with intervening soil berm) of the segment extending north along the highway, downstream of this tight bend.

Recommendations: Clean out the sediment under and in the vicinity of the 9th Street crossing. Conveyance through the straight reach between the two roads could be enhanced if the corridor width could be enlarged, allowing bank slopes to be reprofiled to a lower angle. Alternatively, retaining walls and a low flood bench could be constructed to create an enlarged cross section within the existing stream corridor width, although this would probably be expensive and may not be necessary if other potential flood conveyance improvements are implemented. It would have the advantage, however, of being a highly visible improvement. (Also, it would be a chance to demonstrate that there are "hard" or "engineered" but still environmentally-sensitive stream corridor rehabilitation treatments appropriate to, and often necessary in, highly urbanized environments – a "bioengineering" approach is not realistic on many urban stream segments.) The ornamental shrub hedge on the right bank could be replaced with native trees and shrubs for improved shade and some degree of "re-naturalization."

We agree that the double-channeled segment of Sequoia Creek paralleling Highway 99W should be rehabilitated by eliminating one of the channels and removing the high, steep soil berm between the two channels. Material from the berm can be used to fill the redundant channel. A broad, low flood bench and increased flood channel conveyance capacity would thereby be created. Extensive tree plantings on both sides of the channel would shade the channel and flood bench, eventually reducing flow-retarding grass and shrub growth in the lower floodway cross section. As an added measure, the right bank at the tight bend, where the creek turns north along the highway, could potentially be excavated into an "alcove" which would promote sedimentation in this area. This could be easily accessed for periodic cleanout from the shoulder of the highway.

Stewardship Opportunities: Tree planting and maintenance to insure successful plant establishment.

Location: Highway 99W to Railroad Crossings

Observations: The tight right bend at the inlet to the highway culverts, smaller capacity of the twin box culverts here (as compared to 9th Street), offset channel (abrupt jog left) in the narrow area between the highway and railroad crossings (and complex hydraulics here), and the relatively small span of the railroad bridge itself must all contribute to upstream backwater effects. This is a quintessential situation limiting urban stream rehabilitation, for flood relief or anything else.

The twin box culverts under Highway 99 were both dry when visited on April 28. Creek flow was instead discharging from a partly silted in 36-inch concrete culvert set at a lower grade than the box culverts and outletting about 10 feet north of the left box culvert. The hardened invert under the railroad bridge forms a backwater pool which partly drowns this low-flow culvert, enhancing sediment deposition in it. Someone has placed a picnic table in the left box culvert at its upper end. This obviously could become a major conveyance issue, especially as the table racks up additional flood debris during a high flow event.

Recommendations: A major engineering effort would obviously be required to improve conveyance through this reach. Remove the picnic table from the box culvert under Highway 99W.

Location: Railroad Bridge to Belvue Street Crossing

Observations: The channel downstream of the railroad bridge to the Belvue Street crossing borders the Corvallis Recycling Center, which closely encroaches on the left (north) bank. The right (south) bank is tree lined, providing good shade for suppressing in-channel vegetation growth. While the right bank is encroached upon by a trailer park at the east end of this reach, this bank is quite stable, being covered with ivy. Low-flow channel width varies from 3 to 14 feet or so but even the narrow section is "constrained" by low depositional flood benches: the overall trapezoidal cross section is essentially uninterrupted, providing relatively good conveyance (for this creek). "Average" channel width through the reach is about 10-12 feet and the channel is entrenched about 6-8 feet below grade.

There is substantial fine sediment accumulation immediately upstream of the Belvue Street crossing (which consists of three box culverts). This is in the form of a large marginal bar along the left bank, which is now stabilized by herbaceous growth (mainly reed canarygrass), as well as loose, soft sediments in the low-flow channel itself. Plastic trash has blown into the creek corridor from the east portion of the Recycling Center, which consists of a large parking/operations area.

Recommendations: Since infrastructure encroaches closely on the channel in the upstream portion of this reach, conveyance could be increased by excavating the right bank. However, this would require removal of the native riparian woodland here. In order not to eliminate this woody vegetation, a better choice for enhancing conveyance would be the installation of a steep retaining wall in place of the existing ~1:1 slope on the left bank. Here would be another example of where a "hard" channel rehabilitation approach may be the most environmentally-sensitive strategy since this would preserve the right bank area of streamside woodland.

Along the downstream half of this reach, it is the trailer court along the right bank which closely encroaches on the stream channel. The Recycling Center's asphalt parking/operations borders the channel on the left bank. A strip of this area could potentially be taken to allow bank regrading and enlarge the flood channel cross section, thereby preserving the dense tree cover on the right (south) bank. Alternatively, a retaining wall or steep riprap treatment could be placed on this bank.

It would be helpful to require that the Recycling Center place a fence along their property perimeter. This would help keep trash out of the creek.

Stewardship Opportunities: Tree planting and maintenance to insure successful plant establishment (if any bank work is pursued). Clean-up plastic trash in the creek. (Note: This clean-up effort would be somewhat futile if the Recycling Center is not required to fence off its operations area from the creek since this appears to be the major source of the trash.)

Location: Belvue Street to Jack London Street

Observations: The stream corridor segment between Belvue Street and the newly-constructed Jack London Street crossings consists of a relatively high quality riparian woodland of willow, ash, cottonwood, alder, hawthorn and other native species in the sub-canopy vegetative layers (but including blackberry, especially along the edges). This mix of vegetation produces a nearly impenetrable thicket. There is also substantial downed woody debris within the woodland, although this is mostly smaller material. Channel banks are 4-6 feet high, stable, and comprised of silt/clay. Average channel width is on the order of 8 feet and stream gradient is very flat. Lower average channel width results in some sections of relatively deep water (+1 ft.) in this reach. Racoon tracks were first noticed in this better quality habitat area.

The streambed in this reach consists mainly of silt and very fine sand. There is an especially deep and soft in-channel sediment accumulation immediately downstream of Belvue Street, where a dense willow thicket closely encroaches on the channel. The multiple low branches of these plants tend to trap additional floating debris, thereby impeding the flow. Flow expansion after the culverts, along with the dense willow growth, have evidently produced a stilling effect here, causing extra sediment deposition. The channel-crowding growth of willow in this area demonstrates the potential detrimental effects of using willow plantings along narrow and unmaintained urban stream channels where flow conveyance and flood risk are issues.

Recommendations: Maintain this patch of relatively wide stream corridor to the extent feasible. This area serves as a model of the kind of buffer width which would be desirable to maintain along urban streams generally. For improved conveyance through this reach, excavate the excess sediment which has accumulated immediately downstream of Belvue Street and selectively prune the dense willow growth here.

If substantially improved conveyance is required through this reach, a broad, low flood bench could be created along the left (north) bank. This would necessitate the removal of some woody vegetation but would preserve the generally wooded character of the corridor as well as the shade producing canopy on the south side of the stream. The constructed flood bench could actually diversify habitat conditions in this reach, especially if native herbaceous wetland vegetation is planted on the bench. Native shade-tolerant wetland species, such as certain varieties of sedge (*Carex*), are appropriate for this setting.

Stewardship Opportunities: Selective pruning of the willow growth (supervised) at the upstream end of the reach. Planting wetland species on the constructed flood bench if this option is pursued.

Location: Jack London Street to Railroad R.O.W./Conser Street

Observations: This stretch of stream corridor resembles the upstream reach except that it has now recently been encroached upon by new light industrial facilities. As a result, wooded stream corridor width is now on the order of 50-75 feet wide, with the edges disturbed in many areas (promoting blackberry establishment).

The crossing at Jack London Street is newly installed and this has resulted in a de-vegetated left streambank (now covered with erosion control blanket) and a thick accumulation of fine sediment immediately downstream of the box culverts. Sedimentation in this area is enhanced by the backwater caused by at least two large (for this channel) channel-spanning debris jams not far downstream.

There is an old stream crossing approximately 350 feet upstream of the railroad tracks. The fill forming the crossing appears to have been surfaced with asphalt and is now partly overgrown with grass. The fill is pierced by a 7-foot diameter CM pipe which is filled to approximately ½ of its diameter with large quarried rock and silt (or is actually an arch culvert).

Recommendations: Plant woody streamside plants on left bank adjacent to Jack London Street that has been disturbed by construction (small shrubs low, trees along the upper bank). Remove excess sediment from the channel. Remove the existing debris jams in this reach and selectively prune lower bankside woody vegetation to reduce the tendency for future debris jams. Remove the old culverted stream crossing – this forms an unnecessary pinch point in the channel.

Stewardship Opportunities: Selective pruning of woody lower bank vegetation (supervised) within the corridor. Removal of the debris jams. Replanting of the bank disturbed by construction as well as the bank area disturbed by removal of the old crossing. Maintain plantings until established.

Watershed: OAK CREEK

Date: 1999

Location: Mary's River Confluence to Highway 20

Observations: Oak Creek downstream of Highway 20 (Philomath Boulevard) has a narrow functional floodplain but is confined by high,steep slopes which are covered with native woody vegetation (oak, maple, ash, etc.) as well as extensive thickets of Himalayan blackberry. The gravelly streambed downstream in this reach, down to Oak Creek's confluence with the Mary's River, is structurally un-diverse and consists mostly of riffle habitat. Functional (in-channel) large woody debris or other beneficial instream roughness structures are essentially lacking. Nevertheless, the stream in this reach is not channelized and possesses a sinuous channel planform, alternating point bars, and small scour and corner pools. Also on the plus side, much of the gravel in this reach appears to be only moderately embedded. Although channel shading is generally acceptable, improvements are certainly possible.

There is a substantial obstacle to fish passage approximately35 feet downstream of the twin box culverts under Highway 20. The concrete apron extending 20 feet or so downstream from the culverts is suspended 24-30 inches above the downstream streambed (12-18 inches above the water surface), with a residual (low-flow) pool depth below the drop of less than 12 inches. This represents an impassable barrier to most fish under most flow conditions. Flow over the apron and through the highway culverts is extremely shallow during baseflow conditions, creating an additional barrier to fish passage. The fact that a substantial drop (knickpoint) occurs below the culvert apron suggests an overall pattern of channel degradation on this stream, probably promoted by both channelization and runoff-promoting land use changes in the basin upstream. Further vertical channel adjustment to these changes in the reach immediately upstream is prevented by the Highway 20 culverts, which now replace the Mary's River in providing a local base level of erosion and grade control.

Recommendations: Since Oak Creek reportedly harbors anadromous and resident salmonid fishes, it would be highly desirable to eliminate the fish passage obstacle at Highway 20. This can be accomplished by retrofitting the drop with a naturalistic boulder ramp structure with numerous pocket pools at the outlet from the culverts. Another possible strategy would be the creation of a sequence of stepped boulders weirs with intervening small, self-scouring plunge pools. Such a structure would provide fish passage under most flow conditions. Baffles or other roughness structures could also be retrofit onto the smooth floor of the culverts and over the apron surface to further facilitate the movement of fish between Oak Creek and the Mary's River.

The stream reach downstream of the road crossing, all the way to the confluence with the Mary's River, also offers the opportunity to re-introduce instream structural complexity to this section of Oak Creek. Since there is no downstream culverts at risk of plugging, this could be accomplished by installing highly naturalistic structures, such as engineered log jams, which are currently more commonly deployed along natural streams in undeveloped landscapes. Correctly placed, these could help to create scarce pool habitat and valuable instream hiding and holding cover in this reach of stream. Because of the lack of infrastructure encroachment, the presence of a functional floodplain, and the absence of artificial channel pinch points (culverts) downstream, this area represents a relatively rare instance where "looser" wildland stream rehabilitation prescriptions can be employed in an urban setting without appreciable risk.

Location: Highway 20 to 30th Street

Observations: The culvert inverts under Highway 20 were set high enough to impound water upstream, creating a long dammed pool extending upstream past Morris Avenue. The banks in this reach appear to be quite steep but are almost thoroughly disguised by dense blackberry thickets which overhang the water surface. A few clumps of native shrubbery, such as red osier dogwood, also drape over the pool surface in this reach. Channel width is roughly 20 feet, with the channel entrenched approximately 20 feet below the regional grade.

Concrete rubble becomes an important component of the streambed several hundred feet upstream of Morris Avenue, with lower banks locally revetted with this material. This debris forms a relatively steep, rubble-strewn riffle or "chute" below the 90 degree channel bend at what appears to be an apartment complex just west of 26th Street (the channel alignment changes from north-south to east-west at this location). This area of steeper, pinched low-flow channel appears to be fully fish passable. The upstream end of the demolition debris chute forms a low dam, forcing a relatively deep pool floored with bedrock, silt, and heavily-embedded gravels. This pool extends a considerable distance upstream of the bend in the relatively low-gradient reach here.

The outside (left) bank of the 90 degree bend is bare and eroded, apparently as a result of toe scour and resultant soil falls or slab failures. There has been a recent effort to install erosion control fabric and native vegetation along the top of this high, steep bank, apparently for mainly cosmetic reasons. This effort will ultimately fail as it is undermined by progressive bank erosion. Unfortunately, machine access for effective bank stabilization appears to be hampered here by the adjacent apartment building, which encroaches closely on the channel.

A relative dense stand of native overstory vegetation, consisting predominantly of bigleaf maple, Oregon ash, Garry oak and red alder, commences in the vicinity of the bend and continues in a relatively uninterrupted fashion (except for road crossings) all the way upstream to 35th Avenue (and beyond), the end of the area formally investigated. This vegetation provides good canopy coverage and shade to the creek. Although bare or blackberry covered areas are common along the banks, native snowberry is locally abundant in the shrub layer. There are also a few areas along this reach where red osier dogwood and Pacific ninebark shrubs draper over the channel, providing some measure of cover for instream creatures.

The channel through the reach up to 30th Street, although sinuous, is generally entrenched 15-20 feet below the prevailing grade. Bank materials consist predominantly of silt. As bank slopes are ordinarily steep (1:1 and locally steeper), many of the streamside trees in this long reach have suffered extensive root exposure due to scour, making them weakly rooted and prone to toppling. When they do, they are more likely to promote serious bank erosion in this confined reach than provide much fish habitat, especially where they bridge and remain suspended above the low-flow channel (this was observed in this reach). Because of steep,slopes, sterile substrate and dense shade, much the lower bank area is relatively bare and is this subject to scour erosion. Overall, this appears to occur at chronic, not critical, levels, although relatively small, localized scour pockets and pop-out failures are evident. Some areas of undercut roots occur along scour pools within the low-flow channel, providing locally favorable (but areally very limited) fish habitat.

Portions of the very steep banks in this reach consist of old fill material. This is often eroding and, in some cases, weathered cultural debris such as decades-old cans and glass are being exhumed from the fill face by progressive bank erosion. Homemade bank revetments have also been placed in a few areas within the reach between Western Boulevard and Morris Avenue. A few man-made dams composed of demolition rubble and basalt boulders are also present in this reach, although none of these appears to pose any fish passage issues. The caliber of material used in the dams would probably not resist mobilization and disruption by a very large flow. A number of private water diversion structures were also found in this reach. It is highly likely that these pumps are not permitted with a water right. Some of the observed small boulder dams have been erected to pool water and thus facilitate water abstraction.

The streambed upstream of the pool in the vicinity of the 90 degree bend consists largely of soft bedrock (siltstone or mudstone) with sporadic shallow veneers of gravel. The gravel is patchy in occurrence and is for the most part moderately to severely embedded, although there are few small patches which are relatively free of silt, at least at the surface. Instream habitat consists mainly of riffle and glide with a few small bedrock scour pools (some with submerged undercut ledges). There is essentially no instream large woody debris and the channel is roughly 20 feet wide. The dominant impression of the active channel through this reach from a habitat perspective is that it is essentially featureless, with this low channel complexity therefore allowing few holding opportunities for fish.

Fill was apparently placed decades ago along the left bank of Oak Creek to expand the parking area for the University's Parker Stadium. (It appears that fill was placed up to about this same level on the other side of the creek as well.) Incomplete filling on the stadium side of the creek has resulted in the partial preservation of an intermediate level bench or terrace, which is now well forested with oak, ash and maple, between the stadium parking lot and the channel. This bench appears to be generally about 10 feet above the channel bed. This bench must be very rarely subject to flooding given the relatively large active channel cross section and low channel roughness in this reach. The edge of the stadium fill forms a steep slope roughly 6-8 feet high. Drainage from the stadium parking area has caused local gullying along this slope.

Recommendations: This reach of Oak Creek suffers from significant residential encroachment, along both banks downstream of Western Boulevard and along the right (south) bank in the stadium reach. Close encroachment and steep, high bank slopes which are now colonized by relatively large shade-producing trees offers little opportunity for major enhancement efforts. Significant rehabilitation would require the removal of confining infrastructure and the reprofiling (regrading to a lower, stable angle) of over-steepened channel banks. This would in turn require the removal of streamside trees. Such a level of restoration is probably unrealistic in this area.

A limited, adaptive management approach will presumably be required along this reach (as in so many other urban streams with high infrastructure confinement). Since conveyance is not apparently a problem in lower Oak Creek, the focus of streamwork in this area will undoubtedly be on repairing significant bank failures as they occur and are identified. Because of the simplified nature of this stream reach, instream (lower bank) habitat enhancement aimed at creating additional channel complexity should generally be included in these bank repairs. This could include the creation of additional pool habitat in conjunction with an artificial undercut bank, or the placement of roughness elements such as logs, root wads or boulders to create variable velocity zones, gravel traps and small pools. However, any instream structural habitat enhancement attempted should be

carefully planned owing to the high erodibility of lower bank slopes in this reach. Improper design could accentuate local bank erosion and tree falls.

The active bank failure zone at the 90 degree bend in the downstream portion of this reach presently requires stabilization. Since this area includes a significant bend pool (apparently forced by the downstream rubble fill), it would be useful to build low-water structural habitat into this revetment, as discussed above. For example, a log cribwall installed in this highly-confined site could easily incorporate an artificial undercut bank as part of the structure. The revetment could also be designed as a terrace structure, allowing the middle portion of the bank to be planted with shrubby native vegetation such as willow and ninebark, which would eventually drape over the pool. This approach would produce good cover and holding water for fish while solving the bank instability problem.

The left bank adjoining the stadium offers perhaps the only opportunity for a substantial rehabilitation effort in this reach because some portion of the parking area (mainly unpaved) could conceivably be sacrificed. Truly functional rehabilitation in this area could involve substantial reprofiling the waterside slopes, or even lowering, of the remnant flood bench along the left bank. While this would require the removal of large number of established trees, it would also allow the creation of a more natural channel cross section, which in turn would allow energy dissipation and passive flood storage, and improved biological conditions in this reach. Although many trees would be removed, these are on the northeast bank of the creek and thus are not so critical to channel shading as those on the right bank. Any efforts to pull back banks on the stadium side would also reduce erosive pressure on the steep, unstable opposite bank of the stream, where infrastructure encroachment prevents much meaningful work. This would help to preserve the existing large trees here, which are valuable for channel shade. With this level of alterations, instream habitat enhancements could also be conveniently installed as part of the rehabilitation project.

Location: 30th Street to 35th Street

Observations: Note: Flow levels at the time this reach was investigated (12/99) were too high to walk the channel. Blackberry thickets also located prevented access to significant portions of the channel margin.

Rock fill under the 30th Street bridge has created an armored riffle which encourages lateral bank erosion under high flow conditions. This material also appears to force a long backwater pool upstream in this relatively low-gradient reach. The rock accumulation does not appear to create an obstacle to fish passage.

A small boulder dam has been reported approximately 100 feet upstream of 30th Street in a previous discussion of this reach (Benner 1984). This dam was not observed in December of 1999, although it may have been drowned out by the higher stream flow of this time of the year. If this is the case, the dam would presumably be small enough that it is unlikely to preclude fish passage even during lower flows. (The dam may also have been removed by the high flows of the last several years.)

There is a large diameter pipe crossing the channel 30 feet or so upstream of the 30th Street bridge. This was only about one foot or so above the water surface under apparently ordinary winter flow

conditions (12/22/99). This pipe is this at some considerable risk of failure due to debris jams as large toppled trees are in the channel not far upstream and this material (as well as freshly toppled trees; see below) could presumably drift downstream during a very high stream flow period.

After the suspended culvert apron below Highway 20, the next significant fish passage barrier upstream on Oak Creek is an old engineered metal dam, presumably erected for water diversion, located about 250 feet downstream of the 35th Street bridge. This has two spillways which appear passable for larger fish under higher flow conditions but would presumably constitute a barrier to upstream migration under lower flow situations (residual pool depth could not be measured). The pool upstream of the dam appears to have been largely filled with sediment (with a predominantly gravel texture, at least as a surface armor) and a large gravel and sand bar has accumulated along the left bank downstream of 35th Street, which is apparently within the backwater of the dam. Thus, a very large wedge of sediment wedge of sediment has accumulated upstream of this dam.

General channel bed and bank conditions are much the same in this reach as they are below 30th Street. Entrenchment below the regional grade near the 30th Street bridge is roughly 20 feet but this gradually declines upstream until it is less than 10 feet or so near 35th Street. A portion of the remnant floodplain surface discussed earlier is also preserved along the left bank just upstream of 30th Street.

Canopy coverage is generally good, with a similar mix of overstory species as downstream, although Himalayan blackberry thickets are far more abundant in this reach. On the other hand, infrastructure encroachment is less here than along Oak Creek downstream of 30th Street, although what are apparently University facilities do closely approach the channel along the right bank in the lower end of the reach. A number of stormwater pipes associated with these facilities jut from the bank without the benefit of energy-dissipating aprons, causing local bank erosion.

Streambanks are over-steepened and as steep or steeper than in the downstream reach (banks are vertical in a few places) and consist predominantly fine-grained material and non-engineered fills. Demolition debris has been placed as a haphazard revetment in many places and this is itself locally failing and exacerbating scour erosion.

Because of over-steepened banks, many of the trees rooted on these slopes are prone to scour and eventual toppling. Several large fallen trees have accumulated in the channel several hundred feet upstream of 30th Street. Although they are adding structural diversity to the channel, they are also encouraging fluvial erosion and slumping because of the entrenched channel condition. There is large slump scar on the left bank in this vicinity which is 30 feet wide and more than 15 feet high.

The largest observed bank failure observed in this reach was located on the left bank around 700 feet or so downstream of the steel dam. The failed bank is about 75 feet long and 10 feet high. A large tree, still rooted on the lower bank but now partially detached from it by scour, forms the downstream end of the failure zone. This is likely to promote further bank erosion in this immediate area.

Recommendations: Fish passage should be insured at the steel dam. The dam could be removed, although upstream streambed grade has become adjusted to it's presence and removal would presumably result in the evacuation of a huge quantity of sediment (probably much of this consisting of sand and finer fractions) if significant countermeasures were not taken to prevent this. The

excavation and disposal of so much sediment could be costly, although there may be opportunities to "lose" this on site. Significant bank stabilization efforts would also probably be required if the dam were removed outright. The dam could also potentially be retrofit with an engineered fish ladder. However, in the interest of longer term re-naturalization of the creek corridor, it might be preferable to remove the dam and replace it with a fully fish passable and naturalistic grade control structure, presumably constructed of large boulders.

Active bank failures are prominent in ths reach. These should be treated immediately since they represent significant fine sediment sources for the stream. As before, direct structural habitat enhancement should be incorporated within bank treatments wherever feasible. The largest bank failure identified in this reach is readily accessible by machinery. It is likely that this area could be stabilized by the installation of boulder/root wad bank toe (to resist scour and provide habitat), with simple bank reprofiling, erosion control matting installation, and replanting above this.

There are large areas of open space along this reach of Oak Creek. The upstream segment of the stream is mainly bordered by pasture or hay meadow. Since depth of entrenchment is also reduced in this upstream area, bank slope reprofiling and functional floodplain re-creation become viable options (at least from a technical perspective) in this reach of stream. Stream channel / floodplain recoupling and associated instream habitat enhancement and riparian restoration would seem to be a particularly appropriate activity on University property.

Location: Oak Creek Upstream of 35th Street

Observations: Only a small portion of Oak Creek upstream of 35th Street (upstream of the railroad R.O.W., along Washington Way) was briefly investigated in the spring of 1998 (with P. Benner). The channel is incised about 15 feet here and possessed the same general type of native deciduous tree canopy observed downstream (ash, oak, alder, bigleaf maple, cottonwood). Understory vegetation included natives species (e.g. rose, snowberry, red osier dogwood) in addition to dense blackberry thickets and ivy-covered areas. Much of this woody riparian vegetation has grown up through old fills and revetments of demolition debris. At least in this small area, instream habitat complexity was generally far greater than found downstream of 35th Street. Complexity is provide by apparently stable undercut tree roots and toppled large woody debris, including a few *bona fide* woody debris jams (in 1998). Unfortunately, extensive dumping this area has significantly impacted the visual quality of the channel.

Apart from those already mentioned, the only other known fish passage barrier between the Mary's River and the higher-quality habitat in the rural areas upstream of Harrison Boulevard is the water diversion dam located just downstream of Harrison. This appears to create an impassable fish barrier.

Where locally observed (such as at road crossings, Bald Hill State Park), much of Oak Creek in the rural area upstream of the main Oregon State University Campus appears to possess good water quality and surprisingly clean, potentially spawnable gravels. Riparian canopy coverage is also generally good in the areas observed and depth of entrenchment is usually much less than on the lower reaches of the stream within the urban area.