APPENDIX D. OAK CREEK STREAM SURVEYS

Oak Creek Reach 1 (Confluence with the Mary's River to U.S. Highway 20)

Incision: 3.5 meters (11.5 feet)
Width: 3 meters (9.8 feet)
Bankfull Width: 5.5 meters (18 feet)
Substrate: Gravel/sand

Oak Creek reach 1 is approximately 120 meters (393.7 feet) long. Habitat in the reach is composed of alternating pools and riffles. A lateral scour pool with undercut banks and a depth of 1.0 meter (3.3 feet) provides the best habitat in the reach. Lack of pool depth and a scarcity of large woody debris (LWD) limit instream cover available to fish in this reach. Besides the deep lateral scour pool, no habitat exceeds 0.7 meter (2.3 feet) in depth, and one piece of LWD is present in the wetted channel. The dominant substrate in the reach is gravel, but sand and other fine sediment make up a significant component of the substrate. Substrate embeddedness was estimated to be approximately 40%.

The channel in reach 1 is deeply incised; small areas of bank erosion occur throughout the reach. The largest area of bank erosion occurs at LP 3 where the creek is scouring against the right bank, causing the undercutting of a large tree. The deep incision of the channel precludes over-bank flows and stormwater storage during high flows. A low terrace is present on the left bank near the top of the reach.

The riparian vegetation provides shade to approximately 55% of the stream channel. Overstory tree species include red alder (*Alnus rubra*), white oak (*Quercus alba*), Oregon ash (*Fraxinus latifolia*), and willow (*Salix* sp.). The continuity of the riparian area in the vicinity is disturbed by the numerous road crossings, residential developments, and cleared areas.

A 1-meter- (3.3-foot-) tall cascade located at the outlet of the double box culvert under Highway 20 creates a barrier to fish passage.

Oak Creek Reach 2 (Highway 20 road crossing to location upstream from 53rd Avenue crossing)

Incision: 3.5 meters (11.5 feet)
Width: 4.5 meters (14.8 feet)
Bankfull Width: 7.0 meters (23 feet)
Substrate: Gravel
Gradient: < 1%

Reach 2 of Oak Creek is a deeply incised channel with marginal fish habitat. A 150-meter (492.1-foot) section of the channel has been straightened to accommodate the 35th Street road crossing. Long, slow, glide-like pools separated by short riffles dominate the aquatic habitat. The undercutting of standing trees and deep pockets of scour create cover for fish. Only four pieces

of LWD were found in the surveyed portion of the reach. This small amount of woody debris contributed little to instream cover. Gravel is the most common substrate, but it is usually embedded in silt and other fine sediments. The high level of fine sediments makes the substrate unsuitable for salmonid spawning. Riffle habitat is often created by riprap accumulations in the stream channel.

Streambanks in the reach appear to be stable. The upper portions of the banks are composed of erodible soils, while the channel bottom and lower bank are composed of a slightly erodible cemented alluvium. Riprap and concrete debris line many portions of the bank. In many cases it was unclear whether the debris was intended to stabilize the streambank or whether the streambank was used as a disposal site for demolition debris. Because of its deep incision and lack of low terraces or a floodplain, reach 2 functions primarily as a conveyance system during periods of high flows; its value as salmonid habitat is marginal.

The riparian area along reach 2 consists of two narrow strips of trees and shrubs. The width of the riparian corridor rarely exceeds 20 meters (65.6 feet) and often does not extend beyond the top-of-bank. Despite the lack of sufficient riparian buffer, the Oregon ash, red alder, and big-leaf maple (*Acer macrophyllum*) growing along the streambank shade approximately 70% of the channel.

Oak Creek Reach 3 (beginning just upstream from 35th Street to Walnut Boulevard)

Incision: 2.5 meters (8.2 feet)
Width: 4.5 meters (14.8 feet)
Bankfull Width: 9.0 meters (29.5 feet)
Substrate: Gravel
Gradient: < 1%

Reach 3 of Oak Creek contains suitable but relatively unproductive fish habitat. The pool to riffle ratio is approximately 2.2 to 1. High quality pool habitat occurs sporadically throughout the reach. The dominant substrate is quarter-sized gravel that is moderately embedded in sand and fine sediments. The amount of silt and sand in the substrate decreases toward the top of the reach, resulting is marginally suitable spawning substrates in the upper half. Thirty-two pieces of LWD and one woody debris jam were observed in the 407 meters (1335.3 feet) of reach 3 that were surveyed. The debris jam and pieces of LWD create significant instream cover for rearing salmonids. Refuge for salmonids also was provided by the numerous undercut root masses of standing riparian trees.

Streambanks in reach 3 are generally stable: approximately 2.8% of the streambank in the surveyed portions of the reach were eroding. Low terraces and side channels may have a moderating effect on stream energy. When flooded, these low terraces and side channels help diffuse the stream's energy and prevent the current from becoming concentrated against any one section of the bank. Without them, bank erosion probably would occur more frequently.

The riparian buffer in reach 3 varies in width. Near the downstream end of the reach, it frequently extends less than 10 meters (32.9 feet) beyond the top-of-bank. Near the bike path, the riparian area resembles the native gallery forest and wetlands that historically occurred in the area. It is more than 100 meters (328.1 feet) wide in many places and contains many native plant species. Toward the top of the reach, the riparian area narrows; it does not extend far beyond the top-of-bank. The overstory is composed primarily of Oregon ash, but red alder also is present. Understory shrubs include salmonberry (*Rubus spectabilis*), red osier dogwood (*Cornus stolonifera*), Pacific ninebark (*Physocarpus capitatus*), and snowberry (*Symphoricarpos albus*). The riparian area is fragmented by one road/bike trail crossing.

A pop-up dam located just below Harrison Boulevard creates a barrier to fish passage when the weir boards are in place.

Oak Creek Reach 4

Incision: 2.5 meters (8.2 feet)
Width: 3.0 meters (9.8 feet)
Bankfull Width: 6.0 meters (19.7 feet)
Substrate: Gravel with significant amounts of silt and clay
Gradient: 1%

Reach 4 of Oak Creek is low-gradient incised channel. The stream channel is generally narrower and more steeply incised than in reach 3. The concentration of LWD in the reach is less than in reach 3 and the potential for recruitment has been reduced by infringement on the riparian area by agricultural fields. Moderately embedded gravels (approximately 30% embeddedness) dominate the substrate. Both the quality and quantity of instream cover and off-channel habitat available to fish has been reduced by lack of LWD recruitment and increased incision in the stream. The deeply incised, narrow channel offers little opportunity for the creation of off-channel habitat that provides refuge for fish during high flows. The scarcity of LWD in reach 3 has led to a lack of instream shelter and shallower pool depths than would be expected in pristine habitat.

The narrower channel width and lack of low terraces in reach 3 has led to increased bank erosion. Approximately 9% of the streambanks in the surveyed portion of reach 4 are actively eroding. Because high flows cannot spread out across terraces or a floodplain, streambanks are exposed to the brunt of high flow events and bank erosion is common. Much of the lower bank and channel bottom is composed of semi-erodible clay. This clay layer inhibits the development of scour pools and is unsuitable habitat for most aquatic invertebrates. This relatively impermeable clay layer also precludes hyporheic flow and severs the nutrient and water exchanges between the stream and the riparian area.

The riparian area in reach 3 has been substantially diminished by the residential and agricultural development adjacent to the stream. Residential development along Oak Creek Drive occurs near the top of the left bank (south shore). The riparian vegetation in these areas is restricted to the narrow strip of land between the edge of the water and the top of the bank. In other areas, the

stream is closely bordered by agricultural fields and the Oak Creek Drive right-of-way. Canopy closure in the surveyed portion of the reach was approximately 65%.

Oak Creek North Tributary (the tributary originating above Walnut Park) Reach 1

Incision: <1 meter (3.3 feet)
Width: 2.0 meters (6.6 feet)
Bankfull Width: 4.0 meters (13.1 feet)
Substrate: Silt and sand
Gradient: 1-2%

Reach 1 of the North Tributary to Oak Creek is small creek with very marginal salmonid habitat. Historically this reach appears to have been a braided channel flowing through a wide wetland area. The lower half of the reach has been diverted and is now restricted to a single channel by a dike and a constructed channel. Much of the right bank is a dike that appears to have been built to reclaim wetland areas east of the present channel. The new channel was constructed to create a wide v-shaped channel. The gentle slopes of the streambanks may help dissipate the energy of the stream during high flows. Several riprap crossbars have been installed in the stream. The intended function of these crossbars is not known, but they may help prevent the channel from down-cutting and becoming more incised.

Flowing water may be present only seasonally in the reach. The aquatic habitat of reach 1 has been degraded by livestock. At the time of the SHAPIRO surveys, two ponies and one horse occupied a pasture near the confluence of the tributary and Oak Creek. No fences prevented the animals from walking and defecating in the stream. The streambanks appeared degraded from frequent animal traffic and piles of manure were found near the stream. Much of the riparian vegetation was devoid of tree or shrub species and the stream corridor vegetation was similar to the pastureland surrounding the creek. In the other areas, a thin strip of willow grew on either side of the stream. These patchily distributed willows provide marginal stream shading but are too small to provide LWD recruitment potential. A large plunge pool near the confluence of the tributary and Oak Creek has large algae mats. The algae may be the result of increased nutrients from animals defecating in or near the creek.

Few areas of active erosion were observed in the surveyed portion of the reach: one area immediately upstream from the confluence of the tributary with Oak Creek and small patches of bare ground from animal traffic.

North Tributary Reach 2

Incision: 0.5-2.5 meters (1.6 to 8.2 feet)
Width: 1.5 meters (4.9 feet)
Bankfull Width: 3.0 meters (9.8 feet)
Substrate: Silt
Gradient: 2%

Reach 2 is an incised, forested stream channel. Incision of the channel decreases from 2.5 meters (8.0 feet) at the downstream end of the reach to 0.5 meter (1.5 feet) near the top of the reach. Below the Walnut Boulevard crossing are numerous areas of active erosion. The channel in this portion of the stream appears to be down-cutting and widening.

Habitat in this portion of the channel is marginally suitable for salmonids. Pools in the reach appear to have adequate depth to support fish. Pool quality is limited by the lack of LWD in much of the stream. Riffles are often composed of small gravel and sand that may be marginally suitable substrates for resident cutthroat trout.

A forested riparian area borders nearly all of reach 2. The overstory is composed of red alder, Oregon ash, big-leaf maple, and white oak. Hawthorn (*Crataegus* sp.), Himalayan blackberry (*Rubus discolor*), Pacific ninebark, and numerous herbaceous species are present in the understory. Canopy closure above the stream is good, providing shade to approximately 80% of the channel. The riparian area is fragmented by the Walnut Boulevard stream crossing and a large residence located near the top of the reach.

North Tributary to Oak Creek Reach 3 (Walnut Boulevard to headwaters)

Reach 3 is composed of alternating channel and riparian types: a shallower channel with an open canopy and abundant aquatic vegetation, and a deeper channel with a closed canopy. Both channel types are incised approximately 0.3 meter (1 foot) and would allow for high flow events to exceed the banks.

The open canopy channel is most frequent within the boundaries of Walnut Park and is characterized by scattered willows, and small ash trees, and abundant cattail (*Scirpus* spp.), reed canarygrass (*Phalaris arundinacea*), and Himalayan blackberry. The wetted channel averages 0.5 to 1.0 meter (1.6 to 3.3 feet) in width and is usually less than 0.1 meter (.3 foot) in depth. The substrate is dominated by silt and organics, but also contains some gravels and cobble. The riparian area is very thin and usually is bordered by the mowed field of the park. Because of the lack of canopy and abundant aquatic macrophytes, these slowly moving areas are potential sites of water quality degradation. The abundant organic material may result is lowered dissolved oxygen levels and the lack of shade may lead to elevated stream temperatures.

The closed canopy portions of the creek are bordered by mature and medium-aged Oregon ash, white oak, and red alder. Understory vegetation consists mainly of Himalayan blackberry, willow, and snowberry. The riparian area varies between 7 and 25 meters (23 and 82 feet) in width. The aquatic habitat in these areas is composed of an even mix of pools, runs, and glides. The root wads of living trees create channel complexity. As the stream flows through, over, and around the root wads, it becomes braided and creates small areas of scour.

Recommendations: The stream channel should be managed to prevent further incision and to maintain over-bank flows during periods of high runoff. Where incision occurs, streambanks could be sloped back and low terraces could be constructed. Water quality concerns also should

be addressed. Planting riparian trees along the open canopy portions of the stream channel would decrease the amount of aquatic vegetation and moderate temperature increases resulting from solar radiation.

West Fork of North Tributary

The western fork of the North Tributary can be divided into four distinct regions: small headwater streams; the incised portion of the channel; a braided, undefined wetland channel; and the unincised lower channel.

The headwaters of the stream are in a low-density residential development located at the west end of Ponderosa Drive. Impervious surface, roadside ditches, and concrete storm drains have replaced the small ephemeral and seasonal channels that historically comprised the headwaters of the creek.

Downstream from the residential development, the stream channel appears to be down-cutting and has become deeply incised. Incision in some portions of this small channel already exceeds 1.0 meter (3.3 feet). The substrate in the channel is composed of a semi-erodible clay layer, riprap, and gravel. The riparian area along the north side of the channel has been disturbed by forest clearing. Red alder and Oregon ash form the patchy overstory canopy on the north side of the creek. Two residential yards are located within 10 meters (32.8 feet) of the channel on the south side of the creek. The narrow riparian area that separates the yards from the channel is similar to that on the north bank.

As the gradient of the incised channel flattens, the channel incision is lost and the stream fans out into a broad wetland area. With the exception of one shallow 0.2-meter- (.7-foot-) wide channel, no defined perennial channel exists in the wetland area. Instead, traces of numerous ephemeral channels are apparent throughout the wetland. The soils in much of the wetland were mucky and saturated with water at the time of the survey. Overstory vegetation in the area consists of Oregon ash and red alder. Himalayan blackberry appears to be invading many areas of the wetland, and what appears to be a native wetland prairie is present on the northern edge of the wetland.

After dispersing into the wetland, slow, seepy flows converge again to create a more defined channel near Walnut Park. This portion of the stream adjacent to Walnut Park is a low gradient stream bordered by narrow wetland riparian areas. The overstory vegetation is composed of Oregon ash and red alder. The understory vegetation includes Himalayan blackberry, snowberry, and a variety of herbaceous plants. The channel is incised approximately 0.3 meter (1 foot), allowing high flows to exceed the banks and inundate the small floodplain during periods of high runoff. A diversity of aquatic habitats (pools, riffles, runs, glides, and small sections of braided channel) is created by the numerous living root masses that border the channel. The seasonality of the stream and the lack of pool depth likely preclude fish from using this portion of the stream.

Recommendations. The broad wetland located below the residential development is an important factor in maintaining the creek's hydrograph. It sponges up runoff and gradually releases it during periods of low precipitation. By detaining and storing water during peak flows, it prevents downstream channel incision and erosion. The slow seepage of water from the wetland maintains summertime flows and moderates stream temperature during the dry season. The large amount of impervious surface located in the headwaters of the stream threatens the functioning of this wetland. As peak flows increase because of increased conveyance and impervious surface upstream from the wetland, the channel may become more defined, begin to down-cut, and become incised. As the incision of the channel increases, the wetland will become perched above the stream, the water table will become deeper, and runoff will be conveyed through the reach more quickly. Downstream erosion will likely increase as a result of higher flood events, and summertime flows will be reduced.

Protecting the wetland may include limiting increases in impervious surface, increasing the amount of stormwater detention, and rehabilitating the incised portions of the channel upstream from the wetland.

Bald Hills Tributary to Oak Creek

Incision: None
Width: 1 meter (3.3 feet)
Bankfull Width: 2.5 meters (8.2 feet)
Substrate: Patchily distributed silt/clay and areas with small, clean gravels
Gradient: 2-3% and increasing toward the top of the drainage

The Bald Hills tributary to Oak Creek is shallow, often-braided wetland channel. Riffles and glides are the dominant habitat types, especially above the Bald Hills Trail crossing. Beaver dams below and just upstream from the trail crossing create potential fish habitat. These small dam pools may provide over-wintering and rearing habitat for cutthroat trout. Silts dominate the substrate in the creek, but patches of small, relatively clean gravel do occur.

The braided and broad wetland floodplain helps moderate the hydrograph in the Bald Hills tributary. The lack of incision allows high stream flows to exceed the shallow streambanks and inundate the floodplain. By absorbing runoff and slowing the movement of water down the drainage, the wetlands smooth the spikes in the hydrograph and prevent downstream erosion caused by peak runoff events. By slowly releasing water stored in the spongy soils of the wetland floodplain during the dry season, the wetland area helps maintain flows into the summer months.

The riparian areas on the tributary are discontinuous, fragmented by the trail corridor and agricultural fields. The majority of the riparian area along the Bald Hills tributary has a closed overstory canopy dominated by Oregon ash and a few red alders. Where the canopy is open, an understory of willow and young Oregon ash is established.

Recommendations: The majority of the watershed is already designated as open space to be preserved. By maintaining this designation, the hydrologic and habitat functions of the drainage would be protected.

Oak Creek Tributary #2

Tributary #2 is located north of Oak Creek Drive and west of Walnut Boulevard. Its confluence with Oak Creek is just downstream from the Walnut Boulevard bridge over Oak Creek. Except for the 200 meters (656.2 feet) of channel upstream from the confluence, the creek is a ditch running through agricultural fields.

The 200 meters (656.2 feet) of stream habitat near the confluence consist of a wetland channel with low, slow-moving flows. Little pool habitat is present and the channel contains dense populations of aquatic vegetation. The substrate is composed entirely of silt. The riparian area in this short section of creek is composed of young Oregon ash and some white oaks that are set back from the channel. Canopy closure is patchy, with many openings.

Upstream from this section of the creek, the channel is a narrow ditch running through a large agricultural field. No riparian vegetation grows along the channel. The ditched section of the creek provides no detention storage of runoff, but conveys flows rapidly to Oak Creek. The high density of aquatic vegetation growing in the creek and in proximity to agricultural fields indicates that it may be contaminated with excess nutrient levels and agricultural chemicals.

Recommendations: Assess nutrient levels and potential for contamination by agricultural chemicals.

Watershed: OAK CREEK

Date: 1999

Location: Mary's River Confluence to Highway 20

Observations: Oak Creek downstream from Highway 20 (Philomath Boulevard) has a narrow, functional floodplain but is confined by high, steep slopes that 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) LWD 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.

A substantial obstacle to fish passage is located approximately 10.7 meters (35 feet) downstream from the twin box culverts under Highway 20. The concrete apron extending 6.1 meters (20 feet) or so downstream from the culverts is suspended .6 to .8 meters (24 to 30 inches) above the downstream streambed (0.3 to 0.5 meters [12 to 18 inches] above the water's surface), with a residual (low-flow) pool depth below the drop of less than .3 meter (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 base flow conditions, creating an additional barrier to fish passage. The fact that a substantial drop (knick point) 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 boulder weirs with intervening small, self-scouring plunge pools. Such a structure would provide fish passage under most flow conditions. Baffles or other roughness structures also could be retrofitted onto the smooth floor of the culverts and over the apron surface to further aid the movement of fish between Oak Creek and the Mary's River.

The stream reach downstream from 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 no downstream culverts are 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" wild land 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 that 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 6.1 meters (20 feet), with the channel entrenched approximately 6.1 meters (20 feet) below the regional grade.

Concrete rubble becomes an important component of the streambed several hundred feet upstream from 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 from 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. A recent effort to install erosion control fabric and native vegetation along the top of this high, steep bank was 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 by the adjacent apartment building, which encroaches closely on the channel.

A relative dense stand of native overstory vegetation consisting predominantly of big-leaf maple, Oregon ash, Garry oak (*Quercus garryana*), 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. In a few areas along this reach, red osier dogwood and Pacific ninebark shrubs drape 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 4.6 to 6.1 meters (15 to 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 caused by 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 they are to 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 thus 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 really 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 the decades-old cans and glass that are being exhumed from the fill face by progressive bank erosion. Homemade bank revetments also have 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 also are present in this reach, although none of these appears to pose any barrier to fish passage. The caliber of material used in the dams probably would not resist mobilization and disruption by a very large flow. A number of private water diversion structures also were 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 aid water abstraction.

The streambed upstream from 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 occurs in patches and is for the most part moderately to severely embedded, although a few small patches that are relatively free of silt, at least at the surface, can be found. Instream habitat consists mainly of riffle and glide with a few small bedrock scour pools (some with submerged undercut ledges). Essentially no instream LWD exists 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 apparently was 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 3 meters (10 feet) above the channel bed. This bench must very rarely be 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 1.8 to 2.4 meters (6 to 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 from Western Boulevard and along the right (south) bank in the stadium reach. Close encroachment and steep, high bank slopes that are now colonized by relatively large shade-producing trees offer little opportunity for major enhancement efforts. Significant rehabilitation would require the removal of confining infrastructure and the re-profiling (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 apparently is not a problem in lower Oak Creek, the focus of stream work in this area undoubtedly will be on repairing significant bank failures as they happen and are identified. Because of the simplified nature of this stream reach, instream (lower bank) habitat enhancement aimed at creating additional channel complexity generally should 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 crib wall installed in this highly confined site could easily incorporate an artificial undercut bank as part of the structure. The revetment also could 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 that eventually would 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 substantially re-profiling the waterside slopes or even lowering the remnant flood bench along the left bank. While this would require the removal of a large number of established trees, it also would allow the creation of a more natural channel cross section, which in turn would allow energy dissipation, 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 as critical to channel shading as those on the right bank. Any efforts to pull back banks on the stadium side also would 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 there that are valuable for channel shade. With this level of alterations, instream habitat enhancements also could be conveniently installed as part of the rehabilitation project.

Location: 30th Street to 35th Street

Observations: Note that flow levels at the time this reach was investigated (December 1999) were too high to walk the channel. Blackberry thickets also prevented access to significant portions of the channel margin.

Rock fill under the 30th Street bridge has created an armored riffle that 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 30.5 meters (100 feet) upstream from 30th Street in a previous discussion of this reach (Benner 1984). This dam was not observed in December 1999, although it may have been submerged by the higher stream flow at this time of the year. If this were the case, the dam would presumably be small enough that it is unlikely to preclude fish passage even during lower flows. (The dam also may have been removed by the high flows of the last several years.)

A large-diameter pipe crosses the channel 9.1 meters (30 feet) or so upstream from the 30th Street bridge. This was only about .3 meter (1.0 foot) or so above the water surface under apparently ordinary winter flow conditions (December 22, 1999). This pipe is at considerable risk of failure from debris jams: 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 76.2 meters (250 feet) downstream from the 35th Street bridge. This has two spillways that 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 from the dam appears to have been largely filled with sediment (with a predominantly gravel texture, at least as a surface armor). A large gravel and sand bar has accumulated along the left bank downstream from 35th Street, which is apparently within the backwater of the dam. Thus, a very large wedge of sediment has accumulated upstream from 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 6.1 meters (20 feet), but this gradually declines upstream until it is less than 3 meters (10 feet) or so near 35th Street. A portion of the remnant floodplain surface discussed earlier also is preserved along the left bank just upstream from 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 from 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 of 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 from 30th Street. Although they are adding structural diversity to the channel, they also are encouraging fluvial erosion and slumping because of the entrenched channel condition. The left bank in this vicinity is marred by a large slump scar that is 9.1 meters (30 feet) wide and more than 4.6 meters (15 feet) high.

The largest observed bank failure in this reach was on the left bank approximately 213.4 meters (700 feet) downstream from the steel dam. The failed bank is about 22.9 meters (75 feet) long and 3 meters (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 ensured at the steel dam. The dam could be removed, although the streambed grade upstream has become adjusted to its presence. Its removal, therefore, would presumably result in the evacuation of a huge quantity of sediment (probably consisting mostly 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 opportunities to "lose" this onsite might be available. Significant bank stabilization efforts likely also would be required if the dam were removed outright. Retrofitting the dam with an engineered fish ladder is another possibility. However, in the interest of long-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 this 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 installing a boulder/root-wad bank toe (to resist scour and provide habitat), re-profiling the bank, installing erosion-control matting, and replanting above this.

This reach of Oak Creek has large areas of open space. The upstream segment is mainly bordered by pasture or hay meadow. Since depth of entrenchment also is reduced in this upstream area, bank slope re-profiling and functional floodplain re-creation become viable options (at least from a technical perspective). 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 from 35th Street

Observations: In the spring of 1998, a SHAPIRO scientist and Patricia Benner briefly investigated a small portion of Oak Creek upstream from 35th Street (upstream from the railroad ROW, along Washington Way). The channel at this location was incised about 4.6 meters (15 feet) here and possessed the same general type of native deciduous tree canopy observed downstream (ash, oak, alder, big-leaf maple, and cottonwood [*Populus* sp.). Understory vegetation included native species (e.g., rose [*Rosa* sp.], snowberry, and 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 from 35th Street. Complexity is provided by apparently stable undercut tree roots and toppled LWD, 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 from Harrison Boulevard is the water diversion dam located just downstream from Harrison. This appears to create an impassable fish barrier.

Where locally observed (such as at road crossings and Bald Hill State Park), much of Oak Creek in the rural area upstream from the main Oregon State University campus appears to possess good water quality and surprisingly clean, potentially spawnable gravels. Riparian canopy coverage also is 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.

Recommendations: Given its relatively favorable conditions, fairly minimal structural improvements and planting efforts could potentially enhance salmonid holding and spawning habitat in the upper reaches of Oak Creek. The upstream area reportedly contains cutthroat trout and conditions could readily be improved for this species. Fully functional channel and floodplain conditions, along with the establishment of a wide woody riparian corridor and stream buffer, also could be achieved with little or no infrastructure impact in this area. These generally favorable (and readily improvable) channel and riparian conditions in the upstream reaches of Oak Creek provide a strong incentive to prioritize removal of all fish passage barriers between Oak Creek's headwaters and its confluence with the Mary's River.