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## **Section 1. Introduction**

URS Corporation (URS) was retained by Pierce County (the County) to develop conceptual design recommendations for culvert repairs at two locations on McCormick Creek, located in Gig Harbor, Washington (see Figure 1). These capital improvement projects were identified in the Gig Harbor Basin Plan (GHBP) (URS 2002).

The culverts at the Burnham/Sehmel Drive NW crossing (Burnham culvert) were determined to be under-sized during the GHBP study. Analysis of the two existing 36-inch diameter culverts showed the road would be overtopped during the 25-year and 100-year storms. Per County direction, the Burnham culverts are to be replaced to reduce flooding.

The culvert at the Wood Hill Drive NW crossing (Wood Hill culvert) was identified during the GHBP field investigation as a partial barrier to fish passage. The outlet of the culvert is perched with an approximate 18-inch drop to the underlying pool. Passage is further impeded by a water diversion structure positioned under the outlet. Per County direction, the Wood Hill culvert is to be retrofitted to improve fish passage conditions.

A private driveway culvert is located in the reach between the Burnham and Wood Hill culverts. The GHBP identified this driveway culvert as a potential hydraulic and fish passage barrier. The potential impact of this culvert on the two culvert repair projects will be considered.

This memorandum presents an assessment of the McCormick Creek culverts and conceptual design approaches for culvert replacement and retrofit. Section 2 describes existing watershed and site conditions from several perspectives. Section 3 discusses culvert repair concepts. Section 4 presents recommended alternatives and provides a preliminary cost estimate. Section 5 identifies additional data required to finalize the designs. Section 6 and 7 provide abbreviations and references, respectively.

Figure 1 – McCormick Creek Culverts Vicinity Map

## Section 2. Existing Conditions

This section presents a qualitative assessment of existing conditions based on review of available documentation and limited field reconnaissance. The following data sources were utilized:

- Two-foot topographic contour data developed from aerial photogrammetry (approximate date 1998)
- Survey data (preliminary date June 2004) of the culvert inlets and outlets, stream banks in the vicinity of the culvert ends, and adjacent roadway embankments.
- Aerial photo (USGS orthographic 2002)
- Existing reports and maps (described in associated sections)

A site visit was conducted on May 19, 2004. URS personnel consisted of engineers Doug Sovern and Alice Lancaster and biologist Rob Nielsen. They were accompanied by County staff engineer Damon DeRosa. Both sites were evaluated, field measurements and photographs collected, and observations recorded. No formal survey data were collected. The team spent approximately 6 hours at the project site.

### 2.1 McCormick Creek Watershed

McCormick Creek is in WRIA (Water Resource Inventory Area) 15 and is designated as stream 15.0065 in the Puget Sound River Mile Index (Ames and Bucknell 1981). The mainstem of McCormick Creek is approximately 1.6 miles long, with a branched tributary contributing an additional 2 miles of channel. The creek originates in a large wetland and flows northwest to Henderson Bay, entering approximately 0.75 miles south of Purdy.

McCormick Creek is crossed by SR 16 at RM 1.0. Most of the flow in McCormick Creek during the May 19, 2004 survey appeared to be coming from tributary 15.0066, which enters the creek from under SR 16 (see Figure 2) at RM 0.89. McCormick Creek drains a catchment area of about 2.5 square miles (1,506 acres). Currently, an estimated 17 percent of the McCormick subbasin is covered by impermeable surface; future build-out conditions are estimated to be 28 percent impervious (URS 2002).

McCormick Creek is confined in a canyon from its mouth to just above Wood Hill Drive (RM 0.67). Upstream of Wood Hill Drive the natural floodplain is functional, but the course of the creek has been modified in most areas where it runs parallel to SR 16. The substrate throughout the watershed is impaired by embedded silt. Gravel operations on both the east and west sides of SR 16 were primary contributors, with recent expansion construction at the prison also causing siltation in the mid-1990s (Haring 2000). Thirty macroinvertebrate samples taken from the creek have resulted in ratings of “excellent,” but results have varied (Haring 2000). Since 1996, results have generally fallen into the “moderate” to “good” range.

Figure 2 – McCormick Creek Site Photo

The reach of the creek below Wood Hill Drive and the forested reach immediately above Wood Hill Drive had both good riparian habitat and large woody debris and good pool frequency and channel complexity. Substrate embeddedness varied between poor and good. The good habit extends across the Wood Hill culvert about 280 feet and ends at RM 0.72.

Above the forested reach, across the driveway culverts, to the culvert at Burnham Drive, the stream flows through an open area with little or no shade and few trees. Above the culvert at Burnham Drive (RM 0.81) to the mouth of tributary 15.0066, riparian habitat consists of dense shrubs, with increased shade but little potential for recruitment of large woody debris. From RM 0.72 to tributary 15.0066 the stream has poor riparian habitat, no large woody debris, and fair pool frequency and channel complexity. Substrate embeddedness varies between fair and poor.

Thirty water quality samples were collected by Gig Harbor High School between 1994 and 1996 (Haring 2000). The average water temperature was 9.33°C, with August water temperatures ranging between 15 and 17°C. Average dissolved oxygen level was 8.23 mg/l and the average pH was 6. The low pH was associated with acidity coming from wetlands associated with the headwaters of the creek. The average discharge was 9.81 cfs and ranged between 1.6 and 17.5 cfs. USGS measurements near the mouth of the creek from February 1978 to January 1979 documented flows ranging from 4.64 cfs in May to 1.15 cfs in August. The 25-year recurrence interval storm flow under 1990 land use conditions was estimated to be 230 cfs (Haring 2000, GHBP 2002).

### **2.1.1 Vegetation**

The dominant riparian trees in the forested portion of the creek below RM 0.72 were western Redcedar (*Thuja plicata*), bigleaf Maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and western hemlock (*Tsuga heterophylla*). Common riparian shrubs were Indian plum (*Oemleria cerasiformis*), salmonberry (*Rubus spectabilis*), devil's club (*Oplopanax horridus*), thimble berry (*Rubus parviflorus*), red elderberry (*Sambucus racemosa*), Oregongrape (*Berberis nervosa*), and red huckleberry (*Vaccinium parvifolium*). Common understory herbs were wild lily-of-the-valley (*Maianthemum dilatatum*), skunk cabbage (*Lysichitum americanum*), field horsetail (*Equisetum arvense.*), stinging nettle (*Urtica dioica*), Pacific bleeding heart (*Dicentra formosa*), trailing blackberry (*Rubus ursinus*), sword fern (*Polystichum munitum*), and deer fern (*Blechnum spicant*).

The mown riparian area surrounding the driveway culverts was dominated by Perennial rye grass (*Lolium perenne*), creeping bentgrass (*Argostis stolonifera*), Kentucky bluegrass (*Poa pratensis*), sheep fescue (*festuca ovina*), quack grass (*Agropyron repens*), redtop bent grass (*Argostis gigantea*), velvet grass (*Holcus lanatus*), soft brome (*Bromus mollis*), foxtail barley (*Horedum jubatum*), and orchard grass (*Dactyulis glomerata*).

An open riparian area surrounding a small pond and immediately below the culvert at Burnham Drive was dominated by bracken fern (*Pteridium aquilinum* var. *pubescens*), lady fern (*Athyrium Filix-femina* var. *cyclosorum*), sedge (*Carex spp.*), rush (*Juncus spp.*), reed canary grass (*Phalaris arundinacea*), thimble berry (*Rubus parviflorus*), field horsetail (*Equisetum arvense.*), and Himalayan blackberry (*Rubus armeniacus*). Two

Douglas-firs (*Pseudotsuga menziesii*) were near the riparian area on both sides of the culvert at Burnham Drive and a few scattered willows (*Salix spp.*) and red alders (*Alnus rubra*) occurred near the stream banks, providing what little shade was available in the open reach of the stream.

The reach above the culvert at Burnham Drive was dominated by Sitka willow (*Salix sitchensis*), Scouler's willow (*Salix scouleriana*) Pacific willow (*Salix lucida* ssp. *lasiandra*), and red alder (*Alnus rubra*), with an understory of Indian plum (*Oemleria cerasiformis*), salmonberry (*Rubus spectabilis*), thimble berry (*Rubus parviflorus*), scotch broom (*Cytisus scoparius*), Himalayan blackberry (*Rubus armeniacus*), reed canary grass (*Phalaris arundinacea*), field horsetail (*Equisetum arvense.*), and sword fern (*Polystichum munitum*).

### 2.1.2 Wildlife

Typical mammals in the watershed are black bear (*Euarctos americanus*), Columbia black-tail deer (*Odocoileus hemionus columbianus*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), longtail weasel (*Mustela frenata*), Townsend meadow mouse (*Microtus townsendii*), deer mouse (*Peromyscus maniculatus*), moles (*Scapanus spp.*), and shrews (*Sorex spp.*).

Birds observed within the forest canopy or shrub willow above the Burnham Drive culvert during the site visit were downy woodpecker (*Picoides pubescens*), Pacific-slope flycatcher (*Empidonax difficilis*), Willow flycatcher (*Empidonax trailii*), American crow (*Corvus brachyrhynchos*), Steller's jay (*Cyanocitta stelleri*), chestnut-backed chickadee (*Parus rufescens*), bushtit (*Psaltriparus minimus*), red-breasted nuthatch (*Sitta Canadensis*), winter wren (*Troglodytes troglodytes*), golden-crowned kinglet (*Regulus satrapa*), Swainson's thrush (*Catharus ustulatus*), yellow warbler (*Dendroica petechia*), Common yellowthroat (*Geothlypis trichas*), spotted towhee (*Pipilo maculates*), song sparrow (*Melospiza melodia*), and American dipper (*Cinclus mexicanus*) near the stream channel.

Birds observed in open areas during the site visit were northern flicker (*Colaptes auratus*), violet-green swallow (*Tachycineta thalassina*), barn swallow (*Hirundo rustica*), American crow (*Corvus brachyrhynchos*), Marsh wren (*Cistothorus palustris*), American robin (*Turdus migratorius*), European starling (*Sturnus vulgaris*), fox sparrow (*Passerella iliaca*), white-crowned sparrow (*Zonotrichia leucophrys*), dark-eyed junco (*Junco hyemalis*), red-winged blackbird (*Agelaius phoeniceus*), house finch (*Carpodacus mexicanus*), and American goldfinch (*Carduelis tristis*).

### 2.1.3 Fish Use

Several salmonids have been documented in McCormick Creek (Blakley et al. 2000, Haring 2000, SASSI 1994, Williams et al. 1975, GHBP 2002). Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), and steelhead trout (*Oncorhynchus mykiss*) have been observed as far upstream as RM 0.89 (just beyond the Burnham culverts) and coastal cutthroat trout

(*Oncorhynchus clarki clarki*) have been observed as far upstream as RM 0.20 of tributary 15.0066.

A spawning aggregation of about a dozen brook lamprey (*Lampetra richardsoni*) were observed during a site visit on May 19, 2004 spawning immediately below the culvert at Wood Hill Drive by URS biologist Rob Nielsen. Coho salmon and cutthroat trout juveniles were observed during the site visit below the culvert at Wood Hill Drive and cutthroat juveniles were observed above and below the Burnham culvert. It is likely that brook lamprey occur at least as far upstream as cutthroat trout have been reported. Haring (2000) reports that Chinook salmon reported in McCormick Creek are likely periodic strays. Considering the proximity of McCormick Creek to the Minter Creek hatchery complex, any Chinook salmon are likely stray hatchery fish.

Other species of fish that may occur in McCormick Creek (Mongillo and Hallock 1995, Wydoski and Whitney 2003) are river lamprey (*Lampetra ayresi*), Pacific lamprey (*Lampetra tridentata*), resident rainbow trout (*Oncorhynchus mykiss*), speckled dace (*Rhinichthys osculus*), threespine stickleback (*Gasterosteus aculeatus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), reticulate sculpin (*Cottus perplexus*), torrent sculpin (*Cottus rhotheus*), and shorthead sculpin (*Cottus confusus*).

**2.1.4 Hydrology**

Estimated streamflows for McCormick Creek at the Burnham and Wood Hill culverts are presented in Table 1.

<b>Table 1 – McCormick Creek Flows</b>			
Flow	Culvert		Source
	Burnham	Wood Hill	
Baseflow	0.8 cfs	0.8 cfs	1
Fish Passage Flow	28 cfs	28 cfs	2
2-Year Peak Flow	69 cfs	69 cfs	3
25-Year Peak Flow	193 cfs	195 cfs	3
100-Year Peak Flow	245 cfs	250 cfs	3
Sources:			
1. Base flow estimated as average of minimum discharges measured during the months of June to September 2000 and 2001 (stream gauge measurements taken as part of the GHBP. (URS 2002)			
2. Fish-passage design flow for the month of January estimated using regression equation for Region 2 (Puget Sound) lowland stream (standard error added). (WDFW 2003)			
3. Peak flows predicted for existing conditions using the Army Corps of Engineer’s HEC-HMS model. (URS 2002)			

**2.1.5 Geology**

On the Geologic Map of Washington – Northwest Quadrant (Dragovich, et al, 2002) the project area is mapped near a contact between undifferentiated outwash deposits and till. Till consists of an unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and boulders deposited directly by glacial ice. Till soils are a good foundation

material, are somewhat difficult to excavate, and may present some design and construction challenges for anchoring instream structures. Slopes in till soils may be up to vertical and still exhibit good slope stability.

Undifferentiated outwash deposits consist of recessional and proglacial (or advance) stratified sand and gravel. Most likely, the outwash at the project area is advance, not recessional, because the map shows the outwash only near the streambed, and therefore stratigraphically lower than the glacial till. Recessional outwash would not be covered by glacial till. The significance of recessional versus advance outwash has to do with the level of compaction. Advance outwash has been compressed by the glacier, so it provides better foundation material and slope stability than recessional outwash. Outwash soils are a good foundation material and are easier than till to excavate and install timber structures. Slopes in advance outwash soils may be quite steep and still exhibit good slope stability.

## 2.2 Wood Hill Drive Crossing

The Wood Hill Drive crossing consists of one 60-inch diameter concrete culvert. Table 2 lists the physical parameters associated with the culvert. Additional data collected during the site visit are presented in Appendix A.

<b>Table 2 – Wood Hill Culvert Characteristics<sup>1</sup></b>	
Inlet invert elevation (feet)	79.20
Outlet invert elevation (feet)	78.64
Length (feet)	113.2
Slope (percent)	0.5
Upstream embankment height (feet) <sup>2</sup>	22.0
Downstream embankment height (feet) <sup>2</sup>	22.6
Upstream channel bed width (feet) <sup>3</sup>	8.1
Downstream channel bed width (feet) <sup>3</sup>	9.3
Average channel slope (percent) <sup>4</sup>	1.7
Notes:	
<sup>1</sup> Based on June 2004 survey data (Vertical datum is NGVD 29)	
<sup>2</sup> Embankment heights from culvert invert to road crest	
<sup>3</sup> Average distance between bank “toe” points	
<sup>4</sup> Calculated from water surface elevations at up-and downstream survey extents	

### 2.2.1 Riparian Conditions

The riparian habitat above and below the Wood Hill culvert is dominated by a mixed conifer/hardwood forest, which provides both shade and good recruitment of large woody debris to the stream channel. The reach of stream immediately above and below the culvert rates good for both riparian habitat and the presence of large woody debris.

### **2.2.2 Fish Habitat Conditions**

The stream above the Wood Hill culvert is in a wooded ravine. The channel has a pool:riffle ratio of 40/60, with most of the pools approximately 6 to 12-inches in depth and tailouts about 2-inches deep. Average bankfull width of the channel is about 10-feet, with a low flow channel approximately 3 to 4-feet wide. The stream has a moderate gradient (2 percent) contained channel. Channel gradient is about 3 percent immediately above the culvert. Substrate consists of 20 percent sand, 30 percent small gravel, and 50 percent large gravel. The floodplain is about 25-feet wide near the culvert and widens to about 50-feet about 60 feet upstream. The substrate was lightly to moderately embedded. Fish habitat in this reach is good.

The stream below the Wood Hill culvert flows through a wooded ravine. The culvert hangs about 18-inches above a plunge pool of approximately 25-feet in width and 2 to 3-feet in depth. The channel below the plunge pool has a pool:riffle ratio of about 50/50, with pools 10 to 14-inches deep and tailouts about 3-4 inches deep. The channel from the culvert to the end of the plunge pool's tailout has a gradient of about 1 percent, becoming 2 percent downstream. The channel in the vicinity of the plunge pool has mixed controls, but becomes confined downstream from the plunge pool. The average bankfull width of the channel is about 12-feet, with a low flow channel approximately 4 to 5-feet in width. Substrate consists of 10 percent sand, 30 percent small gravel, 30 percent large gravel, 20 percent small cobble, and 10 percent large cobble. The floodplain is about 50-feet wide in the vicinity of the plunge pool, becoming approximately 25-feet wide below. The substrate was lightly to moderately embedded. Numerous rearing coho juveniles and cutthroat trout were observed in this reach. The quality of fish habitat in this reach is good.

### **2.2.3 Fish Passage Conditions**

The Wood Hill culvert is likely a complete barrier to chum salmon at any flow because of an approximately 18-inch drop from the hanging culvert to the pool below the culvert. (See photos in Appendix B.) Passage is made even more difficult because the water falls approximately 6-inches from the culvert lip into a water diversion structure for a remote site incubator (Haring 2000) for what appears to be a private fish hatchery. A 1.5-square foot steel grate covers the diversion structure where the water enters. Shortly below the grate, excess water spills about 12-inches over the left side (looking downstream) of the diversion structure into the pool below the culvert. Although chum salmon are strong swimmers and can negotiate steep chutes, they rarely will attempt jumps over even the smallest falls (WDFW 2000). The water diversion structure is apparently not removed during adult migration (Haring 2000). The culvert is partially passable at some flows by adult cutthroat trout, Chinook, coho, and steelhead migrating upstream (WDFW 2000, 2003, Cupp et al. 1999, Kahler and Quinn 1998, USFW 1992). Upstream passage is impossible for juvenile salmonids. The culvert is likely a barrier to brook lampreys and other non-salmonid fishes.

**2.2.4 Hydraulic Analysis**

This section presents hydraulic analyses conducted to evaluate existing conveyance capacity, fish passage conditions and sediment transport for the Wood Hill Drive NW crossing.

Conveyance Capacity

The capacity of the Wood Hill culvert was evaluated for the 25- and 100-year peak storm flows. Ratios of the headwater to the culvert diameter were estimated using nomographs for concrete pipe operating under inlet and outlet control. The downstream boundary condition for outlet control calculations was assumed to be a free flow condition at the outlet (i.e., no tailwater) because there is a free outfall at low flows and no downstream control to cause backwater at higher flows. The nomograph analysis determined that the culvert operates at the transition between inlet and outlet control during the 25- and 100-year flows.

Results for the capacity calculations are summarized in Table 3. To interpret the results, they can be compared to WSDOT and Pierce County standards or recommendations for culvert capacity. WSDOT requires that the headwater-to-diameter ratio not exceed 1.25 during the 25-year flow event (WSDOT 2004). In addition, WSDOT recommends that culverts be designed such that the roadway is not overtopped during the 100-year flow event. Pierce County storm drainage standards suggest that the headwater-to-diameter ratio not exceed 1.5 during the 100-year flow event (Pierce County 1997).

Frequency	Flow <sup>1</sup> (cfs)	Control	HW/D <sup>2</sup>	Headwater <sup>3</sup> (ft)	Embankment Height <sup>4</sup> (ft)	Freeboard <sup>5</sup> (ft)
25-Year	195	Transition	1.4	6.8	22	15.2
100-Year	250	Transition	1.7	8.7	22	13.3

Notes:  
<sup>1</sup> Peak flows for existing conditions simulated using HEC-HMS (GHBP).  
<sup>2</sup> Headwater (HW) to diameter (D) ratio estimated using inlet and outlet control nomographs.  
<sup>3</sup> Depth of water above culvert invert from nomograph.  
<sup>4</sup> Height from culvert invert to road crest (calculated from survey data).  
<sup>5</sup> Vertical distance from water surface to road crest.

The headwater-to-diameter ratios for the 25- and 100-year peak flows slightly exceed both the WSDOT and Pierce County criteria. The freeboard (vertical distance from the water surface elevation to the road crest) exceeds 13 feet for both flow conditions. While the culvert at the Wood Hill crossing is slightly undersized (based on headwater-to-diameter criteria), the road embankment height is well above headwater elevation for the 100-year flow and minor flooding is not likely to impact existing upstream structures.

Fish Passage Conditions

Passage conditions were assessed for the fish-passage design flow as defined by the WDFW (WDFW 2003). This flow value was calculated using the WDFW regression

equation for Region 2 (Puget Sound) lowland streams in the month of January and the standard error was added. The January flow was selected (instead of May) because the adult migration periods for the fish species present in the creek occur during the fall and winter. The fish-passage design flow is estimated to be 28 cfs.

The average velocity, depth and Froude number were estimated using Manning’s equation and nomographs for circular channels (considering a variable roughness coefficient). The results are presented in Table 4.

<b>Table 4 – Existing Fish Passage Conditions of Wood Hill Culvert</b>		
Parameter	Estimated Values	Comment
Flow (cfs)	28	WDFW fish-passage design flow
Velocity <sup>1</sup> (fps)	6.1	Exceeds WDFW criterion (<3 fps) <sup>2</sup>
Depth <sup>1</sup> (ft)	1.5	Meets WDFW criterion (>0.8 ft) <sup>2</sup>
Froude Number	0.97	Approaching supercritical flow
Notes:		
<sup>1</sup> Average velocity and normal depth calculated using Manning’s Equation (assuming n=0.012)		
<sup>2</sup> WDFW passage criteria for adult trout and culverts less than 100 feet long (WDFW 2003)		

WDFW suggests a maximum average velocity of 3 ft/s (for culverts greater than 100 feet long) and a minimum depth of 0.8 feet for adult trout. The velocity criterion is significantly exceeded (6.1 fps) and conditions are near supercritical (Froude number approaching 1). Therefore, the culvert is likely a passage barrier to adult fish (due to excessive velocity and turbulent conditions). In addition, it can be inferred that the culvert poses a barrier to juvenile fish. A quantitative evaluation of juvenile passage conditions was not performed as a part of this study.

Currently there is a drop at the culvert outlet (approximately 1.5 feet), which poses a physical passage barrier for most conditions. Passage is likely further impeded by a water diversion structure positioned under the outlet.

Sediment Transport

Sediment transport capacity in the vicinity of the Wood Hill culvert was evaluated using the concept of stream power. Stream power ( $\Omega$ ) was calculated according to the following equation (Simons 1992).

$$\Omega = v\tau_o = v\gamma RS_b$$

where, v = velocity (feet per second)

$\tau_o$  = shear stress (shear force per unit wetted area)

$\gamma$  = specific weight of water (62.40 lb/ft<sup>3</sup> @ 50F)

R = hydraulic radius = flow area/wetted perimeter (feet)

$S_b$  = channel bed slope (feet/foot)

Sediment transport capacity is directly related to stream power (Simons 1992). Stream power is not a quantitative measure unto itself (i.e., there is not an optimal range of stream power values that can be applied between watersheds). Rather, it can be used as a relative measure of sediment transport capacity between adjacent stream reaches. Thus, the power of adjacent reaches can be compared to identify areas which may exhibit aggradation (a reach with a low stream power value relative to the adjacent upstream reach) or degradation (a reach with a high stream power relative to the adjacent upstream reach).

Stream power for the culvert barrel and representative channel cross sections for up- and down-stream reaches were calculated for the 2- and 100-year storm flows. Results are presented in Table 5.

<b>Table 5 – Existing Stream Power in Vicinity of Wood Hill Culvert</b>		
<u>Location</u>	<u>Stream Power (lb/ft-s)</u>	
	<u>2-Year Peak Flow</u>	<u>100-Year Peak Flow</u>
Typical Upstream Reach <sup>1</sup>	5.71	11.83
Wood Hill Culvert <sup>2</sup>	2.81	4.92
Typical Downstream Reach <sup>1</sup>	5.18	13.84
Notes:		
<sup>1</sup> The typical channel geometry and gradients were estimated from survey data and field observations. Existing channel roughness was estimated based on visual inspection for channel components (channel bed, dominant discharge channel banks, overbanks) and the composite channel (equivalent) roughness was calculated as $n=[(\sum(P_i n_i^2))^{1/2}]/P^{1/2}$ , where P is wetted perimeter and n is Manning’s roughness coefficient (Chow 1959).		
<sup>2</sup> Velocity was estimated using Manning’s equation for the 2-year flow. Wood Hill culvert is surcharged at $Q_{100}$ ( $Q > Q_{full}$ ). Calculations assume pipe flowing full, and velocity = $Q_{100}/A_{full}$ .		

Under the 2-year flow condition, the calculated stream power in the upstream and downstream channels is estimated to be higher than the stream power in the culvert barrel. This would suggest that sediment deposition is occurring in the barrel at moderate flows. No sediment accumulation was observed in the barrel. This may be explained by the highly aggrading conditions in upstream reaches. The Burnham and driveway culverts may be preventing significant downstream movement of sediment. So even though the stream power is lower in the barrel, the sediment transport capacity is larger than the sediment supply. It should be noted that if the upstream sediment transport obstructions are eliminated, a higher sediment load would be expected.

Under the 100-year flow condition, the calculated stream power in the upstream and downstream channels is also estimated to be higher than the stream power in the culvert barrel. However, a stream power comparison under high flow conditions is not of value because it does not consider the influence of backwater on sediment transport capacity. During high flows, a backwater exists upstream of the culvert resulting. This backwater results in a stream power reduction and aggradation. Downstream of the culvert, the outlet drop creates a plunging jet during high flows which causes degradation (as evidenced by the plunge pool).

### **2.3 Reach Between Crossings**

The reach between Burnham Drive and Wood Hill Drive is approximately 650 feet in length and flows through private property and through culverts beneath a driveway. Access was prohibited by the owner during the May 19, 2004 site visit, so no observation of the creek or culverts could be done. In addition, no instrument survey was performed. Therefore, the assessment of existing conditions is based on a review of available documentation and limited visual observation from Burnham Drive.

#### **2.3.1 Riparian Conditions**

The stream below the Burnham culverts flows through an open area bordered by a seasonal wetland and a few scattered riparian trees until shortly above the driveway. The stream then flows through a mown grassy area with no riparian trees until it reaches a wooded area at RM 0.72. Riparian cover below RM 0.72 appears to be good (mixed conifer/hardwood forest) for approximately 280-feet. Riparian habitat between Burnham Drive and the private driveway is fair to moderate, becoming poor below the driveway. Riparian habitat becomes good in the lower 280-feet of stream flowing through mixed conifer/hardwood forest above Wood Hill Drive.

#### **2.3.2 Fish Habitat Conditions**

The stream was surveyed on county property for about 100 feet above crossing at Wood Hill Drive and a short distance below the crossing at Burnham Drive. The rest of the stream flowing through property at a private residence was observed from the road. The stream below the crossing at Burnham Drive flows through an open area bordered by a seasonal wetland and a few scattered riparian trees until shortly above a private driveway. The culvert at this driveway (RM 0.78) is reported to be a barrier to fish passage with debris dam formed upstream of the culvert (URS 2002). The stream then flows through a mown grassy area with no riparian trees until it reaches a wooded area at RM 0.72. Riparian cover below RM 0.72 appears to be good for approximately 280-feet. Salmonid habitat in the observed open reach of the stream near Burnham Drive was fair to moderate, but likely degrades to poor to moderate between the private driveway and forested area, due to a lack of shade or channel complexity. Fish habitat in the surveyed section of the forested reach was good and it is likely that most of this reach of stream has moderate to good salmonid habitat.

#### **2.3.3 Fish Passage Conditions**

Based on photographs from taken during the GHBP (see Appendix B), there are two corrugated metal pipe culvert barrels of unknown size. This crossing is reported to be a partial or complete barrier to fish passage (Haring 2000 and URS 2002).

#### **2.3.4 Hydraulic Conditions**

Insufficient data was available to perform a quantitative assessment of hydraulic conditions in the reach between the Burnham and Wood Hill culverts. An assessment of the photographs shows that the barrel sizes of the culverts at the driveway crossing are much smaller than those of the Burnham culverts. In addition, the outlet is perched. From this limited data, it can be inferred that the driveway culverts are undersized, are a partial

or complete fish passage barrier, and limit sediment transport to downstream reaches. Additionally, since they are undersized, they may cause a backwater effect upstream and may affect the conveyance capacity of the Burnham culverts.

**2.4 Burnham Drive Crossing**

The Burnham Drive crossing consists of two 36-inch diameter concrete culverts. Table 6 lists the physical parameters associated with the culverts. Additional data collected during the site visit are presented in Appendix A.

<b>Table 6 – Burnham Culverts Characteristics<sup>1</sup></b>	
<b>Northern or RHS culvert <sup>2</sup></b>	
Inlet invert elevation (feet)	88.70
Outlet invert elevation (feet)	88.18
Length (feet)	43.2
Slope (percent)	1.2
<b>Southern or LHS culvert <sup>2</sup></b>	
Inlet invert elevation (feet)	88.63
Outlet invert elevation (feet)	88.27
Length (feet)	42.7
Slope (percent)	0.8
Upstream embankment height (feet) <sup>3</sup>	6.1
Downstream embankment height (feet) <sup>3</sup>	6.6
Upstream channel bed width (feet) <sup>4</sup>	5.9
Downstream channel bed width (feet) <sup>4</sup>	7.7
Average channel slope (percent) <sup>5</sup>	1.7
Notes:	
<sup>1</sup> Based on June 2004 survey data (Vertical datum is NGVD 29)	
<sup>2</sup> Right and left defined looking downstream	
<sup>3</sup> Embankment heights from culvert invert to road crest	
<sup>4</sup> Average distance between bank “toe” points	
<sup>5</sup> Calculated from water surface elevations at up-and downstream survey extents	

**2.4.1 Riparian Conditions**

Riparian habitat above the Burnham culverts is dominated by shrubby willows [Sitka, Scouler’s, and Pacific willow] with some red alder. The understory consists of Indian plum, salmonberry, thimble berry, and invasive species, such as scotch broom, Himalayan blackberry, and reed canary grass. Although the riparian vegetation in this reach of the stream provides a moderate amount of shade, there is virtually no potential for the recruitment of large woody debris necessary to establish complex channel structure. As a result, riparian habitat in this reach of the stream is poor to fair.

The riparian habitat below the crossing is dominated by low shrubs and herbaceous vegetation with a few scattered willows and red alders near the stream banks. Very little

shade is provided by trees, but overhanging vegetation and undercut banks provide some shade. Although there is no recruitment of large woody debris in this reach of the stream, the undercut banks, anchored by dense riparian shrubs and herbaceous vegetation, along with overhanging vegetation maintain a complex channel structure and adequate shade, providing fair to moderate riparian habitat for salmonids and other fish.

#### **2.4.2 Fish Habitat Conditions**

The stream habitat above the Burnham culverts has very few pools (10/90 pool:riffle ratio), with most of the pools less than 8 inches in depth and tailouts about 1 to 2 inches deep. Average bankfull width of the channel is about 10-feet, with a low flow channel 3-4 feet wide. The channel is moderate gradient (< 2 percent) with mixed controls. Channel gradient is about 10 percent for the first 20 feet of channel above the culvert due to bed aggradation. The lack of pool structure is attributable to an almost total absence of large woody debris, boulders or large cobble. Substrate consists of 25 percent sand, 40 percent small gravel, 30 percent large gravel, and 5 percent small cobble. The floodplain is about 15 to 25-feet in width. Riparian habitat consists primarily of shrubby willows and small red alders, which provide a moderate amount of shade. The substrate is moderately to heavily embedded. Fish habitat in this reach is poor.

The stream habitat below the Burnham culverts has a pool:riffle ratio of about 50/50, with pools 8 to 14 inches deep and tailouts about 2-3 inches deep. The channel in the vicinity of the culvert is low gradient (< 1 percent) with mixed controls. The average bankfull width of the channel is about 8-feet, with a low flow channel 2-3 feet wide. Substrate consists of 10 percent sand, 70 percent small gravel, and 20 percent large gravel. The floodplain is about 80 feet wide with a wide seasonal wetland on the left bank (looking downstream), between the stream channel and the pond (on private property – see Figure 2). Most of the floodplain is between the stream channel and the pond. The substrate is moderately embedded and there is virtually no shade provided by trees, but the soil is stabilized by the dense overhanging vegetation on the stream banks. Most of the pools and riffles have undercut banks, which provide rearing habitat for salmonids and other fishes. The quality of fish habitat in the reach immediately below the culvert is fair to moderate.

#### **2.4.3 Fish Passage Conditions**

Based on field observations, the Burnham culverts do not appear to present a physical barrier to fish passage. Cutthroat trout were observed at this culvert and other resident fish species, such as brook lamprey, may be present. If the culvert at the downstream private driveway crossing (see section 2.3) is passable at some flow stages, coho, steelhead, and Chinook may be present occasionally in this reach of the stream. One of the culverts under SR 16 and the Rosedale culvert upstream of SR 16 are partially blocked with silt, but are not considered complete barriers to fish migration (Haring 2000).

**2.4.4 Hydraulic Analysis**

This section presents the hydraulic analyses conducted to evaluate existing conveyance capacity, fish passage conditions and sediment transport for the Burnham Drive NW crossing.

Culvert Conveyance Capacity

Culvert conveyance capacity was evaluated as described for the Wood Hill culvert. Because the downstream culverts could impede the conveyance, assumptions based on the aerial topography were made regarding the driveway culvert embankment.

The downstream boundary condition for outlet control calculations was assumed to be the backwater originating at the driveway embankment, estimated to submerge the outlet by 2.6 feet. The nomographs predicted that the culverts operate under inlet control during the 25- and 100-year flows. If the culvert is indeed operating in inlet control and the outlet is submerged, a hydraulic jump will occur in the barrel. If there is not sufficient length for a jump to develop, the culvert would operate in outlet control. Because detailed hydraulic analysis is beyond the scope of this study, and because the driveway culverts downstream are a largely unknown factor, the remainder of this analysis assumes inlet control on the culvert. Results are summarized in Table 7.

Frequency	Flow <sup>1</sup> (cfs)	Control	HW/D <sup>2</sup>	Headwater <sup>3</sup> (ft)	Embankment Height <sup>4</sup> (ft)	Freeboard <sup>5</sup> (ft)
25-Year	193	Inlet	3.1	9.3	6.1	Overtopped
100-Year	245	Inlet	5.0	15	6.1	Overtopped

Notes:  
<sup>1</sup> Peak flows for existing conditions simulated using HEC-HMS (GHBP). Flows exceed culvert capacity.  
<sup>2</sup> Headwater (HW) to diameter (D) ratio estimated using inlet control nomographs.  
<sup>3</sup> Depth of water above culvert invert (values exceed embankment height indicating road is overtopped).  
<sup>4</sup> Height from culvert invert to road crest (calculated from survey data).  
<sup>5</sup> Vertical distance from water surface to road crest (values calculate negative indicating road is overtopped).

As with the Wood Hill culvert, the headwater-to-diameter ratio was compared to the WSDOT requirement of 1.25 during the 25-year event and the Pierce County requirement of 1.5 during the 100-year event. The estimated headwater-to-diameter ratios for the 25- and 100-year peak flows exceed both WSDOT and Pierce County criteria, and the roadway is overtopped during both storm events. In fact, the culverts do not have the capacity to pass the 25- and 100-year flows (the required headwater to drive these flows through the pipes exceeds the embankment elevation). The maximum flow conveyed through the culverts (occurring while the roadway is overtopped) is estimated as 144 cfs (72 cfs per culvert). If flows exceed 144 cfs, flooding is predicted. The culverts at the Burnham crossing are significantly undersized compared to the predicted flood flows.

Because the culverts are likely operating in inlet control, replacing the driveway crossing (i.e., eliminating the backwater) would not solve flooding problems. Improving the inlet

conditions of the existing culverts would provide a negligible increase in capacity. Therefore, replacement of the Burnham culverts is recommended.

Fish Passage Conditions

Fish passage conditions were evaluated as described for the Wood Hill culvert. Results are summarized in Table 8.

<b>Table 8 – Existing Fish Passage Conditions of Burnham Culverts</b>		
<u>Parameter</u>	<u>Estimated Values</u>	<u>Comment</u>
Flow (cfs)	28 <sup>3</sup>	WDFW fish-passage design flow
Velocity <sup>1</sup> (fps)	6.6	Exceeds WDFW criterion (<4 fps) <sup>2</sup>
Depth <sup>1</sup> (ft)	1.0	Meets WDFW criterion (>0.8 ft) <sup>2</sup>
Froude Number	1.3	Indicates supercritical flow
Notes:		
<sup>1</sup> Average velocity and normal depth calculated using Manning’s Equation (assuming n=0.012)		
<sup>2</sup> WDFW passage criteria for adult trout and culverts less than 100 feet long (WDFW 2003)		
<sup>3</sup> Analysis assumed half the flow, 14 cfs, through each culvert.		

WDFW suggests a maximum average velocity of 4 ft/s (for culverts less than 100 feet long) and a minimum depth of 0.8 feet for adult trout. This is the most conservative set of criteria for the fish species present in the creek. The velocity criterion is significantly exceeded (6.6 fps) and conditions in the culvert are supercritical (Froude number greater than 1). Therefore, the culvert is likely a passage barrier to adult fish due to excessive velocity and turbulent conditions at this flow condition. In addition, it can be inferred that the culvert poses a barrier to juvenile fish. A quantitative evaluation of juvenile passage conditions was not performed as part of this study.

While analysis suggests that these culverts pose a barrier under certain flow conditions, field observations (see section 2.1.3) suggest that the crossing is not a complete barrier.

Currently there is an accumulation of debris and sediment at the left culvert barrel inlet. (See photos in Appendix B). This is blocking flow through the left barrel and forcing additional flow to the right barrel. This condition is exacerbating passage problems by increasing velocities in the right barrel and presenting a physical blockage in the left.

Sediment Transport

Stream power was calculated as described for the Wood Hill culvert. Estimated stream power for the culvert barrel and up- and down-stream reaches during the 2- and 100-year storm flows are presented in Table 9.

<b>Table 9 – Existing Stream Power in Vicinity of Burnham Culverts</b>		
<u>Location</u>	<u>Stream Power (lb/ft-s)</u>	
	<u>2-Year Peak Flow</u>	<u>100-Year Peak Flow</u>
Typical Upstream Reach <sup>1</sup>	5.64	10.53
Burnham Culvert <sup>2</sup>	4.36	4.77
Typical Downstream Reach <sup>1</sup>	6.47	6.00

Notes:

<sup>1</sup> The typical channel geometry and gradients were estimated from survey data and field observations. Existing channel roughness was estimated based on visual inspection for channel components (channel bed, dominant discharge channel banks, overbanks) and the composite channel (equivalent) roughness was calculated as  $n = [(\sum P_i n_i^2)^{1/2}] / P^{1/2}$ , where P is wetted perimeter and n is Manning's roughness coefficient (Chow 1959).

<sup>2</sup> Velocity was estimated using Manning's equation for the 2-year flow. Burnham capacity exceeded during 100-year flow. Calculations assume pipe flowing full, and velocity =  $Q_{100} / A_{full}$ .

Under the 2-year flow condition, the calculated stream power in the upstream and downstream channels is estimated to be somewhat higher than the stream power in the culvert barrel. This would suggest that some sediment deposition is occurring in the barrel at moderate flows. This is evidenced by the thin layer (1/4 inch) of small material (1/4 inch minus) observed in the bottom of barrel.

Under the 100-year flow condition, the calculated stream power in the upstream and downstream channels is also estimated to be higher than the stream power in the culvert barrel. However, as explained for the Wood Hill culvert, a stream power comparison under high flow conditions is not of particular value. During high flows, a backwater exists upstream of the culvert, due to the undersized culverts, and downstream of the culvert, due to the small driveway culvert. These backwater conditions result in a reduction of stream power and deposition. Sediment aggradation would be expected from upstream of the Burnham culvert (starting at the influence of the backwater) down to the driveway culvert embankment.

### **Section 3. Culvert Repair Concepts**

This section presents concepts for repair of the Wood Hill and Burnham culverts. Per County direction, the Wood Hill culvert is to be retrofitted (not replaced) to improve fish passage conditions and the Burnham culverts are to be replaced to reduce flooding. The concepts are assessed with respect to conveyance capacity, fish passage conditions, sediment transport, habitat impacts, geotechnical design requirements, maintenance, and constructability. Per the scope of work, Pierce County will provide all analysis and assessment with respect to hydrologic analysis, hydraulic performance, transportation impacts, right-of-way constraints, property requirements, and the environmental regulatory requirements.

#### **3.1 Wood Hill Drive NW Crossing**

The culvert at the Wood Hill Drive NW crossing (Wood Hill culvert) has been identified as a barrier to fish passage. The outlet of the culvert is perched with an approximate 18-inch drop to the underlying pool. Passage is further impeded by a water diversion structure positioned under the outlet and flow velocities under some conditions. Design objectives for the culvert retrofit include:

- Eliminating the fish passage barrier at the outlet,
- Improving fish passage conditions in the barrel, and
- Maintaining conveyance and sediment transport capacity to the extent practicable.

The project constraints, and descriptions and assessments of design concepts for the Wood Hill culvert retrofit follow.

##### **3.1.1 Constraints**

Design and construction constraints identified for the Wood Hill culvert retrofit include the following:

###### Working with the existing culvert

Per County direction, fish passage conditions are to be improved by retrofitting the existing culvert and downstream reach. The culvert is not to be replaced.

###### Working within downstream corridor

The valley bottom is flat and wide, and the right embankment is steep.

##### **3.1.2 Concept Description**

In order to improve the stream conditions in the culvert, streamflow needs to be deepened and slowed inside the barrel. This can be achieved through a series of weirs installed downstream of the crossing to step up the water surface elevation to submerge the culvert inlet. A sketch illustrating this concept is provided in Figure 3.

Figure 3 – Wood Hill Culvert Concept Sketch

Weirs can be constructed out of numerous materials; the most common ‘natural’ choices are logs or boulders. In McCormick, log weirs will be necessary because boulder weirs could not provide enough water surface elevation rise. Boulder weirs are more appropriate for steeper sloped streams.

Figure 3 shows a series of “timber stepdowns.” A timber stepdown is a “K” shaped log weir. The weir is composed of six to seven timber logs. The visible logs (above ground) include a “top log”, which spans the channel (perpendicular to flow), and two “weir logs” (with underlying “wedge logs” to prevent seepage) which are oriented in a “V” shape pointing downstream. The top log is anchored using two concrete block anchors. Each weir log is anchored using a screw anchor and is connected at two points to the underlying wedge log and at one point to the top log with driven rebar. At least three boulders are placed on the downstream side of each weir log for ballast. A notch is cut in the top log to convey baseflows. A second notch may be cut in the top log (near the bank) to facilitate amphibian passage.

Submerging the culvert inlet would eliminate the outlet drop and reduce velocities and turbulence in the barrel. To just submerge the inlet, the water surface elevation would need to be raised approximately 2.3 feet (the vertical distance between the pool elevation and the inlet invert). This would require five to six timber stepdown devices, assuming an average spacing of 20 feet between devices and a maximum drop of 0.75 feet per device. More devices may be necessary if the channel is lower in elevation or steeper than estimated; additional survey of the channel bottom will be necessary for the final design.

Because the valley bottom is wide in the vicinity of Wood Hill Drive, some of the weirs cannot span the valley width. Partially buried boulders (three-foot minimum diameter) and logs could be installed to extend from either side of weir logs to the valley slopes. This would prevent flow from permanently bypassing the weirs.

In addition to improving passage, the timber stepdown devices encourage the development of a downstream pool and create an upstream pool during higher flow events. These pools reduce flow velocities, regulate stream power, and provide grade control for the streambed. The pools also provide rearing habitat and refuge from high storm flows and predation. This habitat is particularly well suited for juvenile coho.

At the downstream end of the enhanced reach, the boulders provide bed control to maintain the pool for fish passage.

### ***3.1.3 Assessment of Concept***

The proposed concept, a series of log weirs, will improve fish passage without having to replace a hydraulically-functioning culvert.

#### **Fish Passage**

Submerging the culvert to the inlet elevation will reduce the velocity at the fish-passage design flow over most of the length of the culvert. During design, a detailed backwater analysis will be performed to determine the passage velocities. An additional timber

stepdown may be required to further submerge the culvert to attain desired passage conditions through the barrel.

#### Conveyance Capacity

Submerging the culvert to the inlet elevation is not likely to have a discernable impact on conveyance capacity (whether operating in inlet or outlet control).

#### Sediment Transport

If the upstream sediment transport obstructions (the under-sized culverts at Burnham Drive and the private driveway) are eliminated, a higher sediment load would be expected. In this case, sediment management becomes an important design consideration. Design improvements such as a more efficient inlet or channel reconfiguring may be necessary to ensure sediment continues to move through the system.

#### Habitat Impacts

The series of timber stepdowns would improve fish passage and provide rearing habitat and refuge habitat. The weirs would also create large pools that would inundate some riparian vegetation. This would result in some vegetation mortality.

#### Geotechnical

Geotechnical issues significant for the Wood Hill Drive crossing are maximum safe temporary slopes, possibly permanent slope stability, and methods for tying the ends of the timber stepdown structures into the soil at the ends. Borings at the top of the slopes on either side of the creek near the location of the proposed stepdowns should be done to acquire subsurface information on which to base the final design. Boring depths would probably be on the order of 25 to 35 feet.

Per Pierce County, the project location is shown as a landslide and erosion hazard for 30-plus percent, but is not listed as a critical area. Examination of the survey data shows slopes in the vicinity in excess of 30 percent; thus at least a portion of the site is a "landslide hazard area" according to the Pierce County code. Per this code, all construction within a landslide hazard area or its buffer requires a Geotechnical Report. Detailed requirements for the geotechnical report are presented in the code.

#### Maintenance

Based on past performance of similar installations, these devices function well under storm flow conditions and require little or no maintenance. The anticipated lifetime of a log weir is approximately 25-50 years. Timber stepdown devices could be inspected annually for bank erosion or permanently lodged debris that poses a fish passage barrier.

#### Constructability

The log weirs themselves are not difficult to construct. A temporary access road would need to be created for construction activities, and this will need to traverse some fairly steep terrain. Property acquisition or temporary easements will be required. Construction activities may impact traffic on Wood Hill Drive NW, but the road should not need to be

closed for any extended periods of time. A detour route appears to be available via Sehmel Drive NW and 70<sup>th</sup> Avenue NW.

### Other Considerations

Currently a water diversion structure is positioned under the culvert outlet. The diversion is for a remote site incubator for what appears to be a private fish hatchery. At this time, it is unknown whether the diversion is to be maintained. If so, diversion timing and capacity would need to be determined. If necessary, one of the upstream timber stepdowns can be fitted with a screened intake device to divert water to the off-stream user.

Currently the property for which the stream enhancements are proposed does not belong to the County, although it is understood that a purchase agreement is in negotiation. The available property and right-of-way will need to be evaluated with respect to the project construction and function.

## **3.2 Burnham Drive NW Crossing**

The Burnham culverts are under-sized; the estimated headwater-to-diameter ratios for the 25- and 100-year peak flows significantly exceed the WSDOT and County criteria, and it is predicted that the roadway is overtopped during both storm events. In addition, results of the hydraulic analysis of existing fish passage conditions suggest that the culvert likely poses a fish passage barrier under some flow conditions. Design objectives for the replacement culvert include:

- Eliminating road overtopping for flows less than or equal to the 100-year event,
- Improving fish passage conditions, and
- Maintaining sediment transport capacity to the extent practicable from the upstream to the downstream reach.

The project constraints, and descriptions and assessments of design concepts for the Burnham replacement culvert follow.

### **3.2.1 Constraints**

Design and construction constraints identified for the Burnham culverts replacement include the following:

Maintaining the existing road elevation while providing adequate vertical culvert clearance and acceptable road fill thickness to support design loads on road

The existing 36-inch culverts at the Burnham crossing are covered by approximately 30 inches of road fill, resulting in a road elevation approximately 5.5 feet above the stream channel. It is assumed that a highway load factor of H20 will be required during culvert design to account for the live loads on the road. Typically, at least 14 to 24 inches of road fill is required above standard box or arch culverts to provide adequate load bearing

strength at a crossing, depending on the materials used as fill. In situations where adequate road fill cannot be installed based on the required vertical clearance of the culvert and the road elevation it is possible to install a precast/prestressed concrete slab bridge instead of a standard box or arch culvert. Such slab bridges typically have a depth of 12 inches when sized for H20 loading and a clear span of 12 to 16 feet, and can be used directly as a driving surface or covered with asphalt paving.

Widening the road to meet current County design standards and subsequently lengthening the replacement culvert

The road at the Burnham crossing does not meet the current Pierce County design standard and will need to be widened as a part of the culvert replacement project. The existing road is 21 feet wide with shoulders that range from 4 to 5 feet on either side of the lanes, for a total road width of approximately 30 feet. The minimum design standard is 24-foot wide with 5-foot shoulders, for a total road width of 34 feet. The new road section at the crossing will be approximately 4 feet wider than the existing road. The existing culverts at the crossing pass under the road at an angle of approximately 48 degrees and are an average of 43 feet in length. If a similar culvert alignment is selected for the replacement culvert, the new culvert would need to be approximately 5.5 feet longer than the existing culverts to accommodate the new road width.

Limiting downstream work to within the Pierce County ROW

Because the County does not have permission to perform work on the private property downstream of the Burnham crossing, construction activities at the replacement culvert outlet will be limited to the County ROW.

Addressing hydraulic implications of downstream private driveway culvert

Twin private driveway culverts are located approximately 110 feet downstream of the Burnham crossing. Based on limited data, it appears that the driveway culverts are undersized and limit sediment transport to downstream reaches. The hydraulic performance of a replacement culvert at Burnham Drive may be affected by the presence of the driveway culverts. The replacement culvert must be designed to perform well with this downstream control in place and without this downstream control in place (in case the driveway culverts are replaced in the future).

**3.2.2 Concept Description**

Preliminary analysis suggests that a culvert with a 12-foot horizontal clearance (span) and 4-foot vertical clearance (rise) could likely provide sufficient conveyance capacity and desirable fish passage conditions. Further calculations are required to confirm the culvert dimensions, and establish the culvert slope and bed design.

If a similar culvert alignment is selected for the replacement culvert, the new culvert would need to be approximately 48 feet long (about 5.5 feet longer than the existing culverts to accommodate the new road width). While the alignment (culvert skew relative to the roadway) could be modified to reduce the culvert length, this would increase the

culvert skew relative to the upstream and downstream channel. Increasing the skew may cause the channel to realign and result in bank erosion.. Therefore, a similar alignment and length of 48 feet for the replacement culvert is recommended.

There are two conceptual design options for the Burnham culvert replacement. The first option is a standard concrete box culvert. The walls of a culvert of these dimensions would likely be at least 4 to 6 inches thick. As discussed earlier in section 3.2.1, the existing road elevation is approximately 5.5 feet above the stream channel. Typically, at least 14 to 24 inches of road fill is required above standard box culverts to provide adequate load bearing strength at the crossing, depending on the materials used as fill and the live loading. It is expected that it will not be possible to provide the minimum depth of road fill required at the Burnham crossing if a standard box culvert is used without changing the road elevation at the crossing.

The second option for the Burnham culvert replacement is to install a precast/prestressed concrete slab bridge. A slab bridge of this size with a design loading of H20 would be approximately 12 inches in depth, providing the required vertical clearance for the stream crossing while maintaining the current road elevation. The slab can be used directly as a driving surface or covered with 2 to 3 inches of asphalt paving. To construct a slab bridge, structural concrete headwalls are cast in place to support the slab and reinforced concrete bridge end panels are installed to secure the banks of the stream. Micropiles may be required for the headwalls if the soils do not provide adequate stability and strength for construction and loading. The precast slabs are brought to the construction site and installed with connections to the headwalls. Guardrails are typically installed along the outer edges of the slab.

Either replacement concept would include a bed control structure downstream of the culvert to prevent future headcuts from creating a barrier at the outlet (i.e., drop) or undermining the culvert structure. Because downstream construction activities are limited to the County ROW, it is recommended that a boulder weir be installed just downstream of the outlet.

### ***3.2.3 Assessment of Concept***

The proposed concepts improve hydraulic capacity and fish passage:

#### Conveyance Capacity and Fish Passage

The replacement culvert would be designed to provide sufficient conveyance capacity and desired fish passage conditions. The final culvert dimensions, bed type and slope will be established iteratively to meet depth, velocity, Froude number, stream power and capacity criteria (Table 10).

**Table 10 – Culvert Design Criteria**

<u>Parameter</u>	<u>Criterion</u>	<u>Analysis Conditions</u> (Flow/Location)	<u>Explanation</u>
Depth	≥0.8'	Q <sub>fp</sub> in barrel	WDFW criterion (adult trout)
Average Velocity	≤4 ft/s	Q <sub>fp</sub> in barrel	WDFW criterion (adult trout/ culvert less than 100 feet long)
Average Velocity	≤1.33 ft/s	Q <sub>fp</sub> in barrel	Based on maximum velocity of 2 ft/s (for juvenile passage)
Froude Number	≤0.9	Q <sub>2yr</sub> at inlet and outlet and Q <sub>100yr</sub> in barrel	Maintain subcritical flow regime
Stream Power	Match Channel	Q <sub>2yr</sub> and Q <sub>100yr</sub> in barrel	Maintain stream power continuity- Match upstream and downstream channel stream power ± 10%.
Capacity (HW/D)	<1.25	Q <sub>25yr</sub>	WSDOT criterion (roadway not overtopped during Q <sub>100yr</sub> )
Capacity (HW/D)	<1.5	Q <sub>100yr</sub>	Pierce County criterion (with no saturation of roadbeds)

Notes:  
 Q<sub>base</sub>- Baseflow  
 Q<sub>fp</sub>- Fish-Passage Design Flow  
 Q<sub>2yr</sub>- 2-Year Flow  
 Q<sub>100yr</sub>- 100-Year Flow  
 HW/D- Headwater (HW)-to-Diameter (D) ratio

**Sediment Transport**

Under existing conditions, the sediment transport capacity drops just upstream of the culvert under high flow conditions (due to backwater). This has resulted in considerable sediment deposition upstream of the crossing. When the culvert is replaced with a culvert of higher capacity, significant backwater will no longer occur at the inlet during most high flow conditions. This will initiate a change in sediment transport through this reach; accumulated upstream sediment degrades until equilibrium is attained. In other words, a historical sediment sink will become a temporary sediment source. If the downstream driveway culverts remain in place, the sediment will not travel far because it will be deposited upstream of the undersized culverts.

To the extent practicable, the replacement culvert will be designed to provide continuity of sediment transport capacity (similar stream power, no high head backwater, and no drops) from the reach upstream of the culvert to the reach downstream of the culvert.

There is the additional consideration regarding the conversion from the existing culverts with solid bases to ‘bottomless’ culverts. Without the hard base, it will be possible for the stream to downcut and re-adjust itself to the overall slope it would hydraulically seek. Upstream grade control may be required to prevent destabilization of the stream reach above the Burnham culvert.

### Habitat Impacts

Culvert replacement will improve fish passage, and the transport of sediment and wood. Wood supply above Burnham Drive is limited by the upstream culverts under SR 16.

### Geotechnical

Geotechnical issues significant for the Burnham Drive crossing are foundation bearing capacity and lateral earth pressures. Test pits or borings at the site should be done to acquire subsurface information on which to base the final design. Test pit/boring depth would probably not need to be more than about 10 feet.

### Maintenance

The culvert would be designed to minimize sediment accumulation and bank and streambed erosion.

If it is not feasible to design the culvert for wood passage (due to height restrictions), devices could be installed to block wood upstream of culvert inlet in order to prevent culvert plugging (plugging could reduce conveyance capacity and impede fish passage). In this case, maintenance would be required periodically to remove collected debris and place it downstream of the culvert.

The crossing should be inspected annually and after large storms for bank erosion or permanently lodged debris that poses a fish passage barrier.

### Constructability

This is a conventional construction project. The site is easily accessed from Burnham Drive NW. Construction activities would impact traffic. The road will probably have to be closed, but a detour route is available. Due to the skew of the stream with the road, it will be difficult to construct one side of the road at a time, but may be possible.

### Other Considerations

If a similar culvert alignment is selected for the replacement culvert, the new culvert would need to be approximately 5.5 feet longer than the existing culverts to accommodate the new road width. Lengthening the culvert would result in a small loss of habitat. It is uncertain if this would require mitigation, such as supplementing spawning gravels and/or adding habitat diversity (e.g., woody debris).

The existing driveway culvert downstream of the Burnham crossing is undersized and probably a barrier to fish passage. The culvert currently acts as a downstream control and creates a backwater that likely submerges the Burnham culvert outlet. While the Burnham replacement culvert could be designed to function with the driveway culvert in place, it is recommended that the driveway culvert be replaced with a larger culvert to eliminate this hydraulic control and open up the upstream reaches to fish.

## **Section 4. Recommended Alternatives**

### **4.1 Wood Hill Drive NW Crossing**

Because culvert replacement is not feasible, raising the downstream water surface elevation to submerge the culvert inlet is the only culvert retrofit option available to improve fish passage conditions. Log weirs are required to sufficiently raise the water surface elevation because boulder weirs can not provide the necessary elevation rise. Therefore, installation of a series of timber stepdowns to submerge the culvert inlet is the recommended alternative for the Wood Hill culvert retrofit.

Based on preliminary estimates, five timber stepdown devices would be required, assuming an average spacing of 20 feet between devices and a maximum drop of 0.75 feet per device. Partially buried boulders (three-foot minimum diameter) and logs could be installed to extend from either side of weir logs to the valley slopes (to prevent flow from permanently bypassing the weirs). Bed control boulders would be installed at the downstream end to close off the pool of the downstream timber stepdown.

The creek banks would be planted to establish a dense buffer of native vegetation within the project reach. This would improve the stability of the stream banks, provide shade for the creek, contribute organic matter to the creek system to promote insect production, and provide cover to minimize disturbance of adult and juvenile salmon. Existing non-native invasive plant species would be removed mechanically. Existing trees and large native shrubs would be preserved.

### **4.2 Burnham Drive NW Crossing**

Construction of a precast/prestressed concrete slab bridge is the recommended alternative for the Burnham culvert replacement. A slab bridge will provide the required vertical clearance for the stream crossing while maintaining the current road elevation. Based on preliminary estimates, the bridge crossing would have a 12-foot span, a 4-foot rise and a 48-foot length. A slab bridge of this size with a design loading of H20 would be approximately 12 inches in depth. Although the slab can be used directly as a driving surface, this will over time wear the surface of the bridge and necessitate eventual repair or replacement of the upper surface. The recommended design is to cover the slab surface with 3 inches of asphalt paving. The recommended design also includes 20 feet of guardrail on each side of the bridge.

The recommended design for the slab bridge includes two cast-in-place structural concrete headwalls approximately 4.25 feet in height and 34 feet in length, and four reinforced concrete bridge end panels approximately 6 feet in height and 30 feet in length.

Bed control up- and downstream of the culvert would probably be provided through the use of large (3-foot diameter) boulders with river rock backfill.

The roadway embankments associated with the new and lengthened culvert would be hydroseeded to provide permanent erosion control. Some mitigation may be required for the fill associated with the new embankment fill. Disturbed areas within the stream corridor and County right-of-way could be planted to establish a buffer of native vegetation. This would provide shade for the creek, contribute organic matter to the creek system to promote insect production, and provide cover to minimize disturbance of adult and juvenile salmon. Existing non-native invasive plant species would be removed mechanically. Existing trees and large native shrubs would be preserved.

### **4.3 Cost Estimate**

A conceptual level cost estimate is provided in Table 11. This estimate has the following assumptions:

- Estimate assume projects are performed in conjunction. Cost savings result due to economy of scale for mobilization, landscape establishment, erosion control, etc
- These costs are not included
  - Design
  - Permits
  - Property acquisition
  - Right of way easements
  - Bidding assistance
  - Construction management or oversight
  - Construction surveying
  - Detours for traffic control
  - Utility work (for relocation or landscape establishment)
- Burnham culvert does not require piles for embankment or foundation stabilization
- Potential cost of habitat mitigation for elongation of Burnham culvert not included
- The Wood Hill timber step down cost is inclusive of excavation, logs, anchors, backfill, boulders, and river rock
- Removal or modification of existing water diversion at Wood Hill Drive is not included

<b>Table 11 – Conceptual Level Construction Cost Estimate</b>					
<u>Description</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Costs</u>	<u>Subtotal</u>	<u>Total</u>
MOBILIZATION (8%)	1	LS	\$24,000	\$24,000	\$24,000
TRAFFIC CONTROL	1	LS	\$30,000	\$30,000	\$30,000
<b>DEMOLITION &amp; CLEARING</b>					
Clear, Grub, Haul & Dump	1	LS	\$5,000	\$5,000	
Temporary Tree Protection Fence	120	LF	\$4	\$480	\$5,480
<b>EROSION CONTROL</b>					
Water Bypass Sytem/Fish Removal	1	LS	\$12,000	\$12,000	
Water Pollution / ErosionControl	1	LS	\$5,000	\$5,000	
Silt Fencing	580	LF	\$10	\$5,800	\$22,800
<b>WOOD HILL CULVERT RETROFIT</b>					
Timber Stepdown	5	EA	\$9,000	\$45,000	
Boulder Bed Control	1	EA	\$6,000	\$6,000	
Boulders	30	EA	\$150	\$4,500	
Spawning Gravel	30	CY	\$50	\$1,500	
Additional Structures	1	LS	\$10,000	\$10,000	\$67,000
<b>BURNHAM CULVERT REPLACEMENT</b>					
Excavation, Haul & Disposal	260	CY	\$25	\$6,500	
Shoring, and Cribbing	360	SF	\$10	\$3,600	
Structural Concrete (Abutments/Headwall/Wingwalls)	50	CY	\$700	\$35,000	
Precast Concrete Slab	680	SF	\$30	\$20,400	
Select Backfill	50	CY	\$20	\$1,000	
Aggregate Base	14	TON	\$28	\$392	
Asphalt Concrete Pavement	19	TON	\$70	\$1,330	
Pavement Striping	40	LF	\$40	\$1,600	
Guardrail	40	LF	\$30	\$1,200	
Guardrail Terminals	2	EA	\$2,000	\$4,000	
Boulders	20	EA	\$150	\$3,000	
River Rock	32	CY	\$50	\$1,600	
Boulder Bed Control	2	EA	\$6,000	\$12,000	\$91,622
<b>RESTORATION PLANTING</b>					
Trees, Shrubs, Perennials & Live Stakes	9820	SF	\$5	\$49,100	
Hydroseeding	3600	SF	\$3	\$10,800	
Coir Fabric	4910	SF	\$1	\$6,874	
Landscape Establishment (3 years)	1	LS	\$16,000	\$16,000	\$82,774
<b>SUB TOTAL</b>					<b>\$323,676</b>
<b>30% CONTINGENCY</b>					<b>\$97,110</b>
<b>TOTAL</b>					<b>\$420,790</b>

## **Section 5. Additional Data Needs**

### **5.1 Topographic Survey**

Detailed topographic survey data is available for the culvert inlets and outlets, stream banks in the vicinity of the culvert ends, and adjacent roadway embankments. Additional survey information is needed.

#### Survey Extent

The survey data does not extend far enough downstream of the Wood Hill culvert. At present, the preliminary timber stepdown layout almost extends to the survey edge. To be prudent, survey should 50 feet further downstream. Topography for both the stream corridor and valley/embankment slopes are required.

#### Thalweg

Survey data was not developed for the channel thalweg profile. The thalweg is the deepest point on the streambed at a given cross section. The thalweg elevation should be surveyed at least every 20 feet. The thalweg profile downstream of the Wood Hill culvert is required for timber stepdown layout. In addition, it would be useful to have the thalweg profile for all areas surveyed (to confirm streambed slopes), but it is not absolutely necessary.

#### Reach Between Culverts and Driveway Culvert

Most of the reach between the Burnham and Wood Hill culverts was not surveyed. The private driveway culvert downstream of the Burnham culvert can significantly affect the replacement culvert design. Currently, elevations for the driveway culvert diameters and embankment elevation are a guess. A survey of the reach between the culverts (or at least the driveway crossing) would significantly reduce design uncertainties for the Burnham replacement culvert.

#### Burnham Drive Right-of-way

The survey for the Burnham crossing currently lacks right-of-way. To ensure the culvert replacement occurs only within the County-owned properties, the right-of-way needs to be determined.

### **5.2 Wetland Assessment**

The stream just downstream of the Burnham culverts flows through an open area bordered by what appears to be a seasonal wetland. Further assessment is recommended to determine if this area is indeed classified as a wetland and to identify any permit implications.

### **5.3 Geotechnical Data**

Geotechnical investigation, including subsurface data collection, is required at the Wood Hill culvert to meet the requirements for work in a steep slope and buffer area. Geotechnical investigation, including subsurface data collection, is required at the Burnham culvert to evaluation the soil materials for embankment construction and bridge abutment or foundation design.

### **5.4 Additional Support From County**

A determination of the existing, if any, water rights for the diversion at the Wood Hill culvert is necessary. If the diversion is to be maintained, the timing and flow requirements need to be established.

The County may be acquiring property downstream of the Wood Hill culvert for the construction of the enhanced reach. The boundaries of this property need to be included in the design and construction limits.

## Section 6. Abbreviations

°C	Degrees centigrade
AC	Acre (unit in cost estimate)
cfs	Cubic feet per second, a measure of discharge
COE	US Army Corps of Engineers
CY	Cubic yard (unit in cost estimate)
DOE	Washington Department of Ecology
EA	Each (unit in cost estimate)
LF	Linear foot (unit in cost estimate)
LHS	Left hand side (looking downstream)
LS	Lump sum (unit in cost estimate)
RHS	Right hand side (looking downstream)
RM	River mile
ROW	Right-of-way
SF	Square foot (unit in cost estimate)
SR	State Route
SWPPP	Storm Water Pollution Prevention Plan
SY	Square yard (unit in cost estimate)
TESC	Temporary Erosion and Sedimentation Control
WDFW	Washington Department of Fish and Wildlife
WSDOT	Washington State Department of Transportation

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**Appendix A – Culvert Survey Data Summary Tables**

**Appendix B - Site Photos**