Draft Site and Reach Assessment
Coe Clemmons Creeks
at SR203

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Summary

Report findings:

- The Coe Clemmons Creek watershed is a small, rapidly urbanizing watershed in the Snoqualmie Valley.
- Most of the watershed is upstream from the highway.
- The Coe Clemmons Creek crossing is in a naturally depositional reach, downstream from a steep, confined ravine.
- The culvert is nearly blocked with sediment, both upstream and downstream.
- The floodplain on the upstream side of the highway appears to have aggraded.
- The ravine is full of recent and active landslides starting at about 4+60 and continuing up to 3rd Ave S.
- The stream has incised in recent years, in the ravine upstream from the road. This may have accelerated erosion of the banks and downstream deposition.
- Rapid replacement of forest and pasture with impervious surface may have had an effect on stream flow, particularly peak flows.
- Sediment load will continue to be high in the near future.
- There is potential for debris jam formation and dam break failure at station 11+75 and catastrophic affects downstream.

Report recommendations:

- Replace culvert with a 150-foot long clear-span bridge, allowing the creek to flow uninhibited across its alluvial fan.
- Continue clearing culvert of debris using a Vactor truck until the bridge can be built.

1.0 Introduction

This report presents the findings of a site and reach assessment into the drainage of Coe Clemmons Creek, in Duvall, King County, Washington (Figure 1). The Coe Clemmons (an informal name) watershed is approximately 273 acres in area. The issue is that sediment has accumulated in the channel to the point where there is minimal clearance for water to pass under SR109. There is a risk of catastrophic failure of the road prism should the culvert become plugged. Along with the collapse of the road prism would come the destruction of the City of Duval sewer line, with likely contamination of the Snoqualmie River.

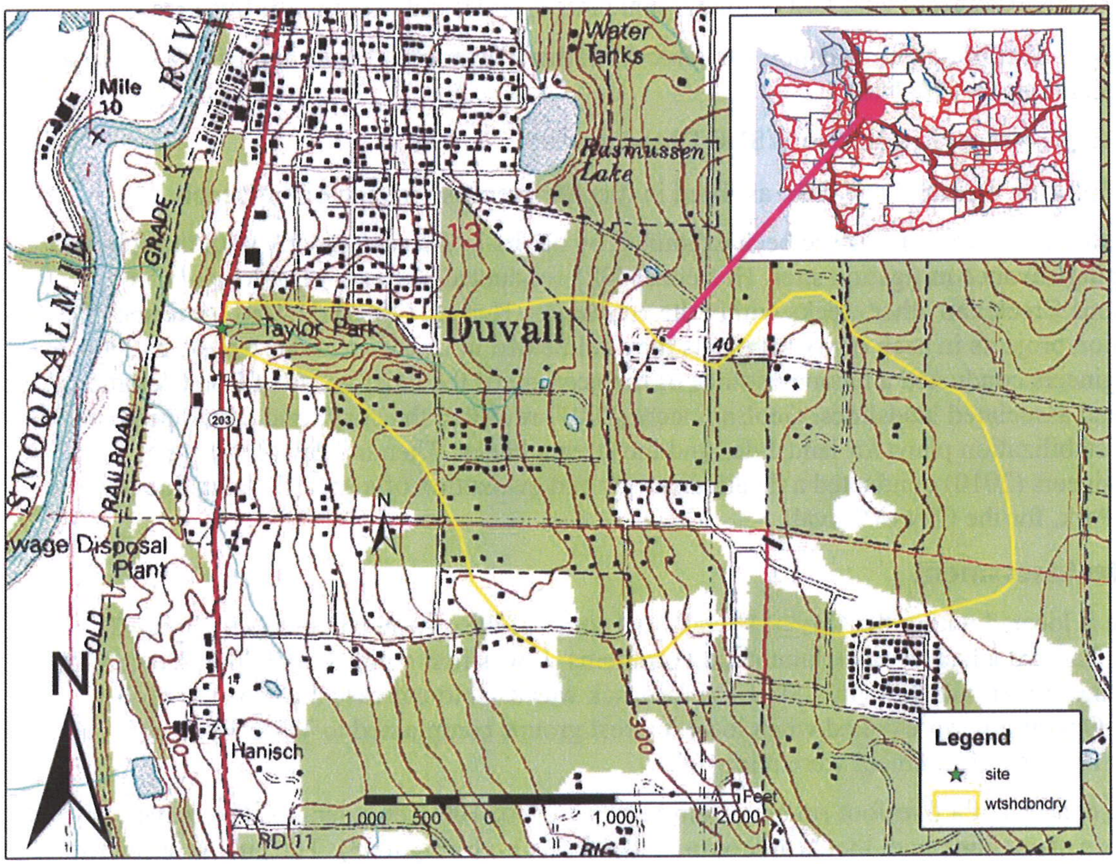

Figure 1. Project location map. Source: USGS topography.

2.0 Methods

This study included literature and data review as well as field reconnaissance. We also conducted synthesis of relevant aerial photos, ground photos taken at the site, topographic maps, geologic maps and reports, fish distribution data, and hydrologic data. Sources of information include:

- Aerial photos taken in 2006.
- Ground photos obtained by environmental staff during site visits in 2009.
- GIS coverages of 24K USGS topographic maps, soils, and geology for this area.
- Fish distribution information available from the Washington Lakes and Rivers Information System (WLRIS).
- Engineering records from WSDOT headquarters.
- Existing literature and data, as listed in the "References" section of this report.

The creek and its watershed have been examined by others in the past, mostly with the aim of developing advance mitigation sites. Herrera (2002) conducted a stream inventory of Coe Clemmons Creek and other creeks within the city limits. Herrera (2006) devised some specific restoration projects in each of six segments they delineated in Coe Clemmons Creek. In 2004, GeoEngineers conducted a reconnaissance of the geology of the inner gorge of Coe Clemmons Creek and associated landslides. GeoEngineers (2007) revisited the gorge and developed conceptual stabilization plans for landslides and the stream banks. Then in May of this year, GeoEngineers (2010) conducted a detailed survey and evaluation of a specific landslide near Taylor Park, for the City of Duvall.

3.0 Site Assessment

The site is located within the City of Duvall, just south of the downtown area (see Figure 2). The site has had a history of sedimentation problems. It was first noticed in 1990 that the clearance in the culvert was low. In 2005 a Vactor truck was used to increase the capacity of the culvert. Operations were halted when local interest groups complained to WDFW. Approximately 10 yards of sediment were removed.

The site consists of a five-foot square concrete box culvert, 100 feet in length. The culvert is located on an embankment that is approximately 20 feet high (Figure 3). The culvert is sloped at 2.3 percent. The embankment spans the floodplain of Coe Clemmons Creek, just above the Snoqualmie River. Only a small portion of the culvert is visible, and the clearance for debris and water is extremely limited (See Figures 4 and 5). The clearance on the upstream side is only about five inches, while on the downstream side, the clearance is about 10 inches. The slope of the culvert is approximately 1.7 percent. During peak flows, there is likely pressure flow through the culvert; that is, there is additional head above the culvert inlet due to ponding. The pressure flow creates a greater amount of shear stress than open channel flow.

Within the embankment above the creek's floodplain is a 12-inch gravity-fed sewer main owned and operated by the City of Duvall. As the highway crosses the Coe Clemmons valley, it dips down to a low point. At the low point, the sewer line is approximately four feet below the surface, or 15 feet above the top of the culvert.

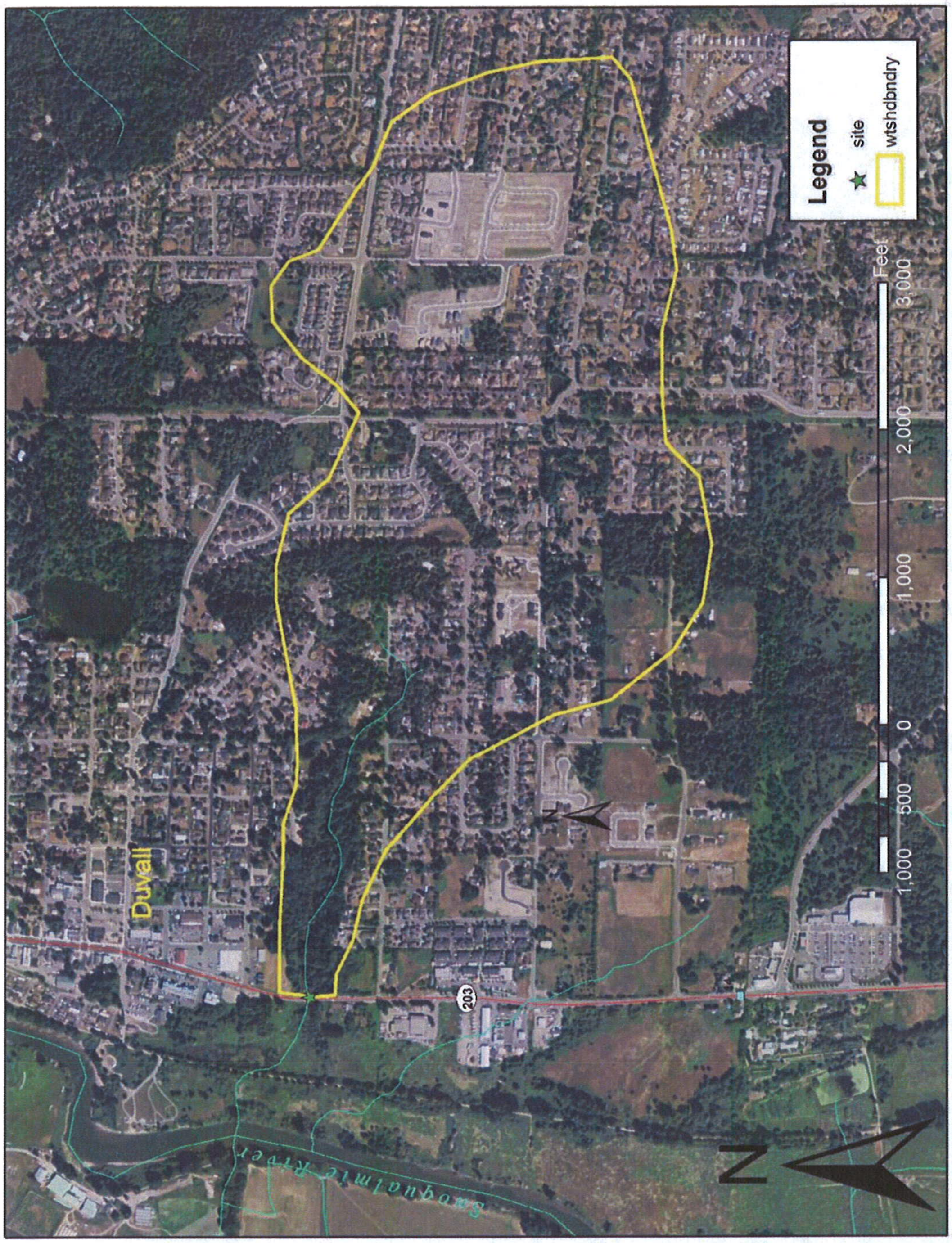

Figure 2. Location of Coe Clemmons Creek watershed with 2009 aerial background.
Source: USDA 2009.

Figure 3. SR203 embankment over Coe Clemmons Creek culvert, looking downstream.

Figure 4. Coe Clemmons Creek at SR203 culvert outlet. Clearance is about 10 inches.

Figure 5. Coe Clemmons Creek at culvert inlet. Clearance is about 8 inches.

4.0 Reach Assessment

4.1 Watershed Conditions and Land Cover

The Coe Clemmons Creek watershed is relatively small, at 275 acres (0.43 mi^2). Although it is relatively low in elevation, with the highest elevation being about 450 feet, it is a relatively steep drainage. The slope of the stream in places reaches nine percent.

The watershed is within the city limits of Duvall, and is mostly developed into single family residences. In 2009, approximately 75 acres, or 27 percent, of the watershed was pervious; this was mostly the gorge reach of Coe Clemmons Creek, and Taylor Park. The rest of the watershed, 73 percent, is impervious, in the form of streets, houses, buildings, and yards. In 2006, the amount of pervious surface was 101 acres, or 37 percent. Therefore a decrease in pervious surface of 10 percent in three years occurred. Figure 6 shows the increase in impervious surface with time in the Coe Clemmons Creek watershed. Note that in this analysis, residential yards were considered impervious. This is because for the most part, the forest and forest soils are completely removed during subdivision construction. It is clear that there has been a dramatic increase in impervious surface within a very short amount of time. In fact, nearly all of the developable land outside the Coe Clemmons gorge has been developed.

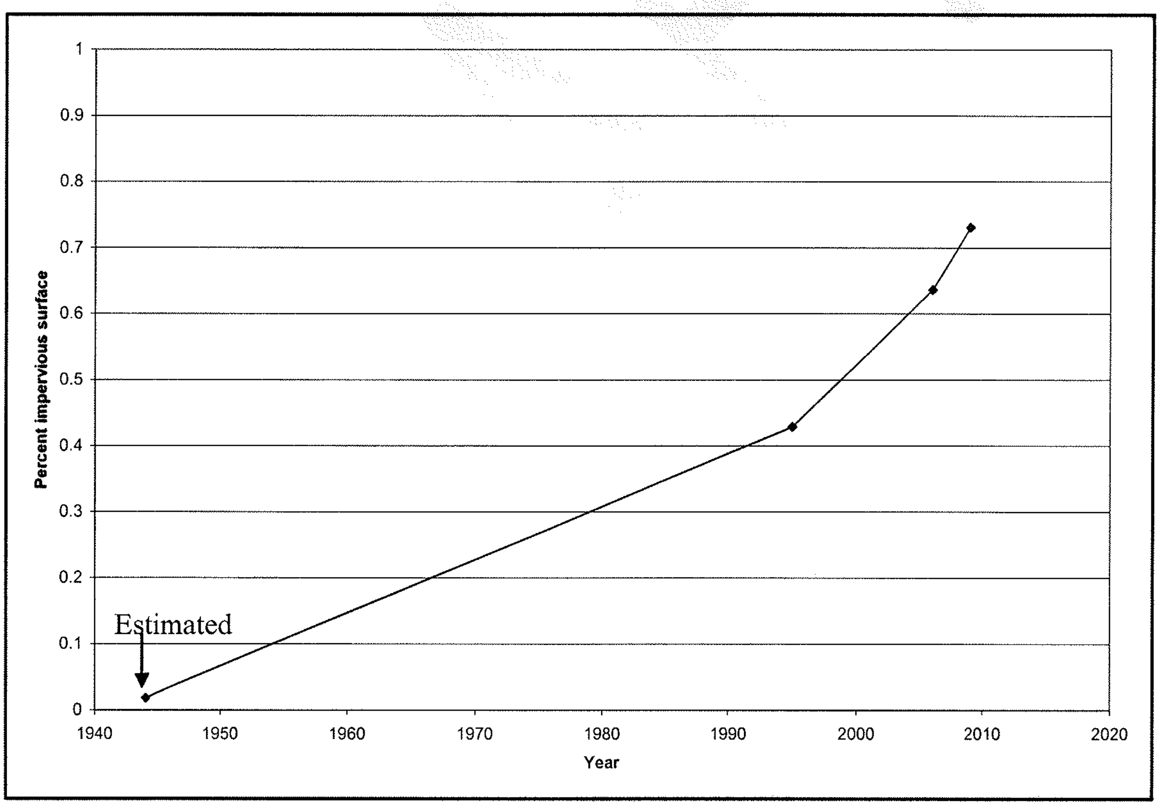

Figure 6. Percent impervious surface area over time, Coe Clemmons Creek watershed.

4.2 Geology and Soils

The watershed is underlain entirely by Vashon till (Booth, 1990). The lowermost reach of Coe Clemmons Creek is formed in recent (Holocene) alluvium from the creek itself and from the Snoqualmie River. There are many exposures of lacustrine deposits within the gorge.

The soils are young and poorly developed, consisting of a forest duff layer over slightly weathered to unweathered parent material. The watershed is underlain by three main soil types. The floodplain area below SR203 is underlain by Nooksack silt loam, which is a deep, well-drained soil. The inner gorge of the creek is underlain by Vailton silt loam, which is moderately deep, poorly drained, and derived from underlying lacustrine sediments. However, the watershed is mostly underlain by Tokul gravelly loam, which is shallow and moderately well drained.

4.3 Geomorphology

The small watershed of Coe Clemmons Creek drains the east slope of the lower Snoqualmie River Valley. It ranges in elevation from about 50 feet to 450 feet above sea level. It has a west-southwest aspect. The stream was divided into three reaches by GeoEngineers (2007), spanning the area between the drainage divide and the culvert at SR203. Reach 1 drains the gentle to moderately sloping plateau above the Snoqualmie River. Reach 2 is the steep, confined gorge sections. Reach 3 was the relatively short section between the mouth of the gorge and the SR203 culvert inlet. A fourth reach is considered in this report, which is the portion of the stream downstream from the culvert to Snoqualmie Trail. Reach 4 is primarily in the alluvial fan section, where the creek enters the very flat Snoqualmie River floodplain. Figure 7 shows the reaches and also the 2003 LiDAR imagery. The topography of the various reaches can be clearly seen. Figure 8 shows a longitudinal profile of the creek with the reaches designated. The stationing used by the City of Duvall is adopted here. Station "0+00" is at the SR203 culvert inlet. Stationing upstream from this point is positive and downstream from the culvert is negative.

Reach 1 is in the upper portion of the watershed, and has been highly modified by suburban development. Portions of the mainstem and its tributaries have been routed through underground pipes. There are several stormwater detention ponds within the upper watershed that attempt to control the rate of flow into Reach 2. The bankfull width is highly variable, and is a reflection of the degree of modification the stream channel has experienced. In the lowermost portion of the reach, the bankfull width is about 15 feet, while the bankfull depth is about three feet. The downstream end of Reach 1 is marked by the 3rd Avenue South culvert and embankment (Figure 9). Much of the coarse sediment load from Reach 1 stops at this culvert.

Reach 2 is in a steep gorge carved into the glacial deposits. The gradient varies from between four and 20 percent. The stream channel is dominated by gravel, with a significant amount of cobbles as well as sand. There are some portions of the stream where boulders form the substrate. We speculate that these are lag boulders from eroded glacial sediment. Between Stations 10+40 to 11+10, these lag boulders form a knickpoint in the stream profile with a gradient of 25 percent. The bankfull width varies from 30 feet near the downstream end of the reach to about 10 feet in the upper portion of the reach. The average bankfull width is approximately 14 feet. Average bankfull depth is about five feet. Figure 10 shows a picture of a typical section of this reach.

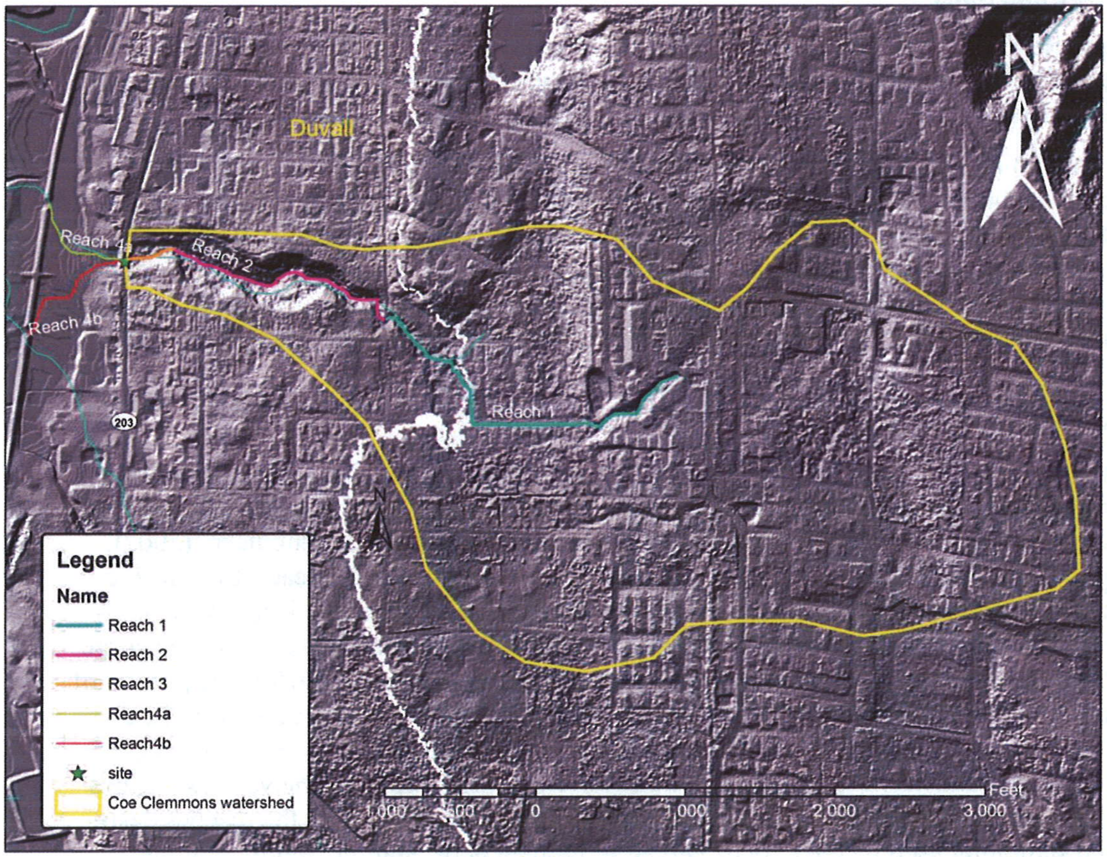

Figure 7. Reach delineation on Coe Clemmons Creek, showing LiDAR topography

Source: King County, 2003.

Figure 11 shows a map of the landslides within the gorge of Reach 2. There are numerous landslides, mostly coming from the left bank, but also there is a large landslide complex on the right bank. Active (or recently active) landslides were found at stations 4+50, 6+00, 8+75 (Figure 12), between at station 10+00 and Station 12+70, and between Station 16+00 and 17+90. There is a large landslide complex at station 1100. There is evidence of very recent and active landslides in this section (Figure 13). There is also a large log jam complex in the stream channel (Figure 14). There is a hazard of a large debris dam forming here because there are several landslides of various sizes immediately upstream. A debris jam could dam the stream, with the associated threat of a dam break flood. The Herrera (2006) survey did not note the presence of landslides in this area; however the GeoEngineers (2007) report, just a year later, described the landslide complex in some detail. An additional study was conducted in December of 2009 on the right bank landslides at station 11+50 (GeoEngineers, 2010).

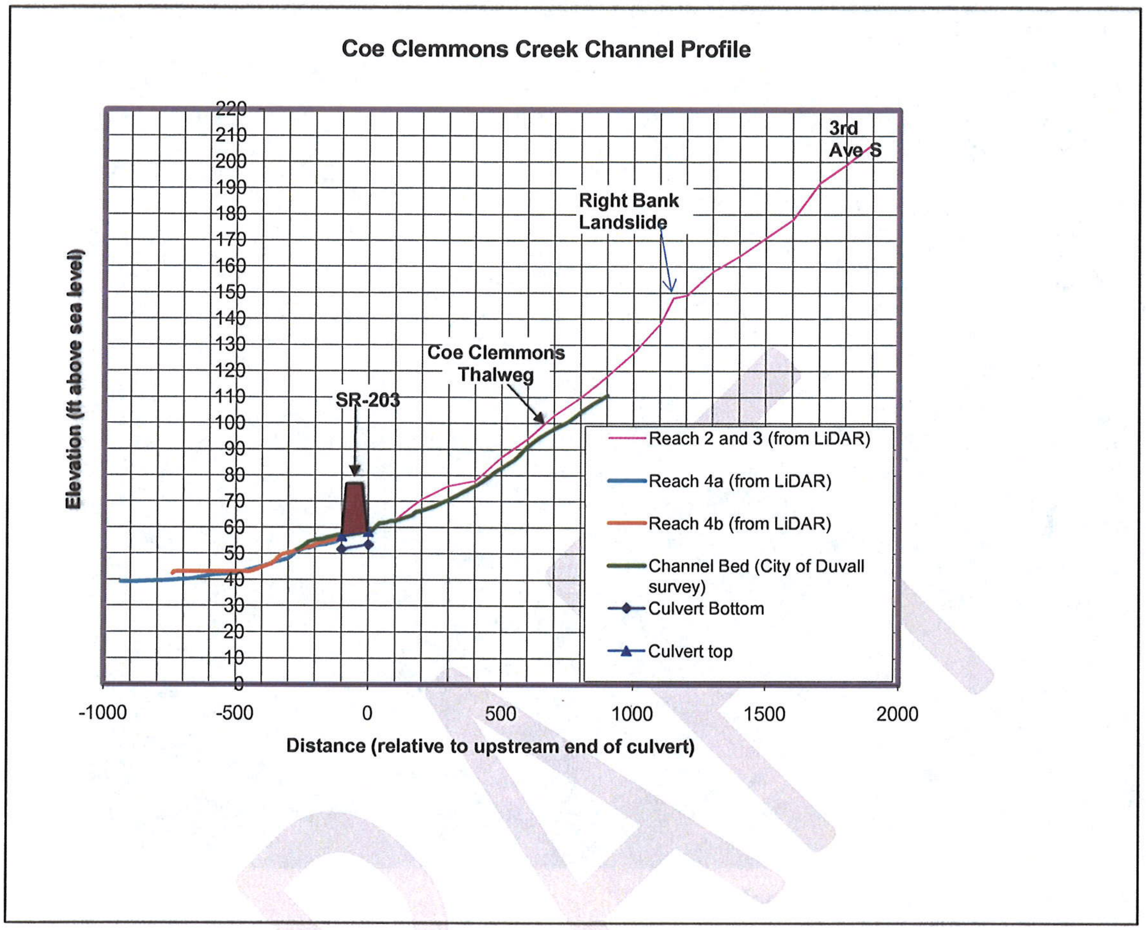

Figure 8. Longitudinal profile of Coe Clemmons Creek, showing reaches 2, 3, and reach 4a and 4b.

Source: City of Duvall, 2009.

Figure 9. Culvert across Coe Clemmons Creek at 3rd Ave., downstream end of Reach 1.

Figure 10. Typical cross-section, Reach 2.

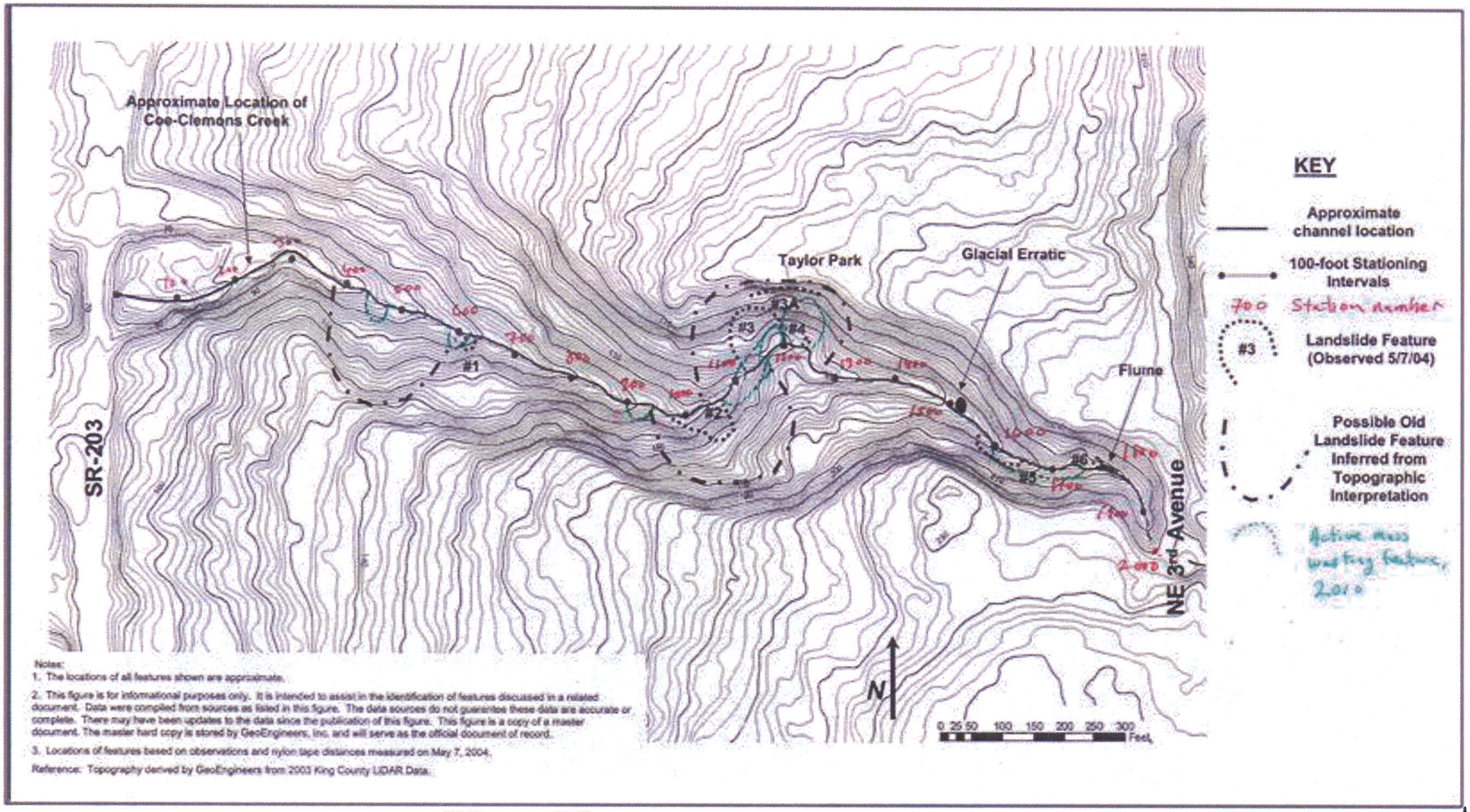

Figure 11. Map of active and ancient landslides, Reach 2, Coe Clemmons Creek.

Source: after GeoEngineers 2007.

Figure 12. Earth flow/slide at Station 8+75, left bank at bottom left of photograph.

Figure13. Streambank sloughing at Station 11+50. Ground at the base of the slope is saturated and easily mobilized.

Figure 14. Debris jam at base of landslide complex at 11+75.

Reach 3 is defined by the end of the gorge of Reach 2 at the upstream end, and the embankment of SR203 at the downstream end. The creek's floodplain changes rapidly downstream from Reach 2, becoming much wider while the stream channel becomes much shallower, with a Dbf of only about three feet, and a Wbf of up to 30 feet. Figure 15 shows a typical view of Reach 3. In addition, springs emanate from the base of the valley sidewall near the upper end of this reach. There are multiple channel threads through the relatively broad floodplain. The lithology of the coarser material is a heterogeneous mixture dominated by intrusive igneous and metamorphic rocks. Near the SR203 culvert, the top of the floodplain tread is one to 1.5 feet higher than the top of the culvert itself. The multiple channel threads converge abruptly and steeply upstream from the culvert. There is evidence of recent sediment accumulation (see Figure 16). The gradient decreases from three percent to one percent in the vicinity of the culvert.

Reach 4 is predominately a depositional reach, including the alluvial fan of Coe Clemmons Creek. The slope of the channel rapidly decreases away from the SR203 culvert, as the creek enters the very flat Snoqualmie River Valley. The slope is less than a tenth of a percent at the lower end of the fan. The stream flows through increasingly thick riparian vegetation (willows), shown in Figure 17. The bankfull width varies between five and 10 feet; the bankfull depth is highly variable, but generally less than two feet. The substrate is dominated by sand, with gravel subdominant. There are few coarse gravels or cobbles. Using the contours developed from LiDAR, it was apparent that there is a portion of the fan that is lower in elevation than the existing channel. There is an obvious low spot into which the channel could avulse. If it did, the stream would flow out of a different opening in the railroad grade. This path was traced on the map and labeled "Reach 4b" while the existing channel is Reach 4a.

Figure 15. Reach 3 floodplain, looking downstream at SR203. Note dead and dying trees.

Figure 16. Recent aggradation in channel in Reach 3, 20 feet upstream from SR203 culvert inlet.

Figure 17. Reach 4, Coe Clemmons Creek. The person in the background is standing on branches 2-3 feet above the stream.

4.4 Hydrology and Flow Conditions

The Coe Clemmons Creek watershed is located in the Puget Lowlands. Its elevation indicates that runoff in the watershed is dominated by rainfall. Watersheds in the Puget Lowlands typically experience peak flows in the winter, and low flows in late summer. In the Coe Clemmons watershed, rain-on-snow events are likely not a significant factor. Being a small watershed, however, suggests that it may be highly sensitive to changes in land use. There is no gage on the stream, though the City of Duvall has plans to install one. Therefore we used the USGS regional regression equations (USGS StreamStats website, 2010) to estimate discharge for peak flows of various return intervals (see Table 1). The peak 2 year flow is about 13 cfs while the 100-year flow is about 40 cfs.

Parameter	Value
Drainage Area	0.4 mi^2
Mean Annual Precipitation	46.8 in.
PK2	13.3 cfs
PK10	24.2 cfs
PK25	30.0 cfs
PK50	35.4 cfs
PK100	39.8 cfs
PK500	52.4 cfs

Table 1. Peak flood flow estimates for Coe Clemmons Creek. From USGS StreamStats website, 2010.

4.5 Riparian Conditions and Large Woody Debris

Riparian conditions are indicative of a watershed in recovery from past logging and development. Riparian vegetation is Reach 1 is limited to narrow bands of remnant trees and shrubs along property lines and between houses and other structures. Reaching the inner gorge (Reach 2), the canopy is dense (70-90 percent), and there is a mixture of western red cedar, alder, and big leaf maple forming the canopy. There are mature conifers (western red cedar and hemlock), cottonwood, big leaf maple, and alder. The understory includes salmonberry, devil's club, vine maple, Indian plum, willow, creeping buttercup, lady fern, skunk cabbage, and sword fern.

The floodplain in the vicinity of the highway (Reach 3) is dominated by non-native and/or invasive plants (blackberry, reed canary grass), and canopy cover is low (see Figure 15). Several trees have died and some are in the process of dying. These dead and dying trees are in the vicinity of the culvert, which suggests that they have been affected by sedimentation.

Downstream of the highway (Reach 4a), a dense thicket of willow with some cottonwood is found. The willow canopy is extremely thick, covering the stream channel to the extent that our reconnaissance took place on top of the willows, with the water surface several feet below our feet (see Figure 17). At the farthest downstream portion of the reach, the willows give way to a thick accumulation of reed canary grass, to the exclusion of nearly any other plant species. Finally, near the old railroad grade, there is a large beaver pond.

A portion of the alluvial fan is less dense, as a result of a wetland mitigation area planting done within the past 10 years (the "Copper Hill mitigation site"). There is a small grove of cottonwoods along the left bank of the creek between the pond and the highway. These trees are part of a mitigation area planted 10 years ago or more. The "low spot" referred to in section 4.3 runs through this area (Reach 4b).

Most woody debris is in Reach 2. This is where the riparian zone is the most intact. Herrera (2006) counted 65 pieces of LWD in this reach. In the areas with recent landslide activity, there are more pieces, as trees have fallen or rotated into the stream channel.

4.6 Fish Utilization and Habitat Availability

According to the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP; WDFW, 2010), coho salmon use Reaches 3 and 4, but do not go farther upstream into Reach 2. Bull trout use the Snoqualmie River where Coe Creek joins it, but they are not shown as using Coe Creek itself. Coho were observed spawning in Coe Clemmons Creek in 2001. These were observed in Reaches 3 and 4. Herrera (2006) estimated that a population of 25 fish was present during surveying in November, 2001.

An extensive aquatic habitat survey was conducted by the City of Duvall (Herrera, 2006). A summary of the habitat types for Coe Clemmons Creek is shown in Table 2. As can be seen, the majority of the habitat is riffles, trench/chutes, and runs.

Habitat Type	Average width (ft)	Average Depth (ft)	Total Length (ft)	Percentage of length
Low gradient riffle	3.5	0.3	2,320.4	33.2
High gradient riffle	5.5	0.4	1,606.8	23
Cascade	6.7	0.6	514.9	7.4
Run	6.6	0.8	713.9	10.2
Trench/chute	2.3	0.4	893.3	12.8
Plunge pool	5.2	0.8	128.1	1.8
Lateral scour pool-log formed	3.9	0.6	33.5	0.5
Lateral scour pool-log rootwad formed	4.5	0.6	6.6	0.1
Lateral scour pool - bedrock formed	3.5	0.7	20.0	0.3
Lateral scour pool - boulder formed	3.9	0.6	49.2	0.7
Dammed pool	27.7	1.1	688.1	9.8
Channel confluence pool	4.1	0.6	14.2	0.2

Table 2. Habitat types for Coe Clemmons Creek. After Herrera, 2006.

5.0 Evaluation of Treatment Alternatives

5.1 Mechanisms and Causes

The culvert on Coe Clemmons Creek at SR203 has become clogged with sediment due to a combination of factors. First, the stream crossing is located in a depositional reach of the stream. Here the stream loses the power to transport its sediment load, as it exits the gorge, and the gradient decreases. The road was placed in an area that was aggrading naturally. The floodplain was completely cut off and the channel confined to five feet. This location in itself would be expected to cause increased aggradation on the upstream side.

Landslides are also playing a critical role in the aggradation at the highway. A cumulative total of 500 feet of actively eroding banks was noted in a reconnaissance in May of this year. These landslides are moving into the creek slowly. The toes of the landslides are eroded by the flood waters. Some of the landslides are deep-seated and are influenced only a little by changes in the peak flows of streams. However in many areas the streambank and the toes of landslides are eroded, removing lateral support for the remaining streambank. Any increases in stream flow (i.e. stream power) would accelerate sediment input into the stream from these landslides and streambanks.

In addition, we suspect there has been an increase in the size and perhaps frequency of floods in the watershed. This is because such a high proportion of the watershed has been converted into impervious surface within the last 20 years. Booth (1990) studied runoff from urbanizing watersheds in this same area, and determined that a common stream response to urbanization was incision. GeoEngineers (2007) reported that the channel was likely incising due to increased peak flows. With the incision, the toes of landslides in the gorge were eroded, and the landslides were activated or reactivated.

5.2 Abating the Primary Mechanisms of Failure

There are several ways to address the sedimentation problems at SR203. In fact, the multi-faceted nature of the problem requires multiple ways of treating it.

One consideration is to reduce the peak discharges on Coe Clemmons Creek. The City of Duvall has recognized that the stormwater runoff needs to be mitigated. The City has been upgrading its stormwater detention ponds for several years, and has plans for more to be constructed in the near future (Boyd Benson, City of Duval Engineer, written communication to Ron Morton, WSDOT, December 14, 2009). The newer ponds are designed not only to prevent an increase in flood peaks, but also to minimize change in the duration of flood events. This will help reduce stream power, slow the rate of incision, and the subsequent undermining of landslide-prone streambanks and hillsides.

Another method of treatment would be to control sediment sources and transport in Reach 2. This has been suggested by several others (Herrera, 2006; GeoEngineers, 2004; 2007). The treatments suggested include:

- Log toe revetments.
- Log and rock toes at the base of mass wasting features.
- Roughness trees.
- Coir logs.

- Drop structures.
- Hillside plantings.

Several of these treatments would be beneficial for long term stabilization of the channel and the hillslopes.

However, the deep-seated nature of the landslides, and the number of and extent of the landslides suggest there will be a high sediment load for the foreseeable future, even if it is mitigated somewhat by these treatments. At the highway, the fundamental element that cannot be changed is the difference in gradient between Reach 3 and Reach 2, and between Reach 3 and Reach 4. The stream crossing will continue to be a depositional reach.

Therefore, to maintain highway integrity, and prevent damage to the sewer line, the long term solution involves changing the stream crossing to accommodate additional sediment loading. Because the clearance in the culvert is currently very small and the sediment load could potentially increase dramatically, interim measures would be required as part of any long term treatment. Short-term and long-term measures to prevent highway damage are discussed in the next section.

6.0 Treatment Alternatives

6.1 Introduction and objectives

The risk of catastrophic failure of the highway and sewer pipe needs to be addressed. As with many projects, there is an inverse relationship between the cost of the solution and the level of acceptable risk. The complexity and expense of the treatment must be weighed against the potential consequences.

The primary objectives of any potential treatment are to:

- Minimize risk to the highway embankment.
- Minimize closures due to flooding.
- Minimize future maintenance costs.
- Ensure the safety and integrity of the highway.
- Maximize natural movement of sediment, woody debris, and water through the reach.
- Minimize impacts to fish and wildlife species, particularly those that are listed as endangered, threatened, or sensitive.
- Minimize impacts to water quality.
- Maintain integrity of the City of Duvall's sewer main.

6.2 Alternatives Considered

Table 3 summarizes the alternatives and their advantages and disadvantages. We considered six main alternatives, including no action (continued periodic dredging as needed). Figure 18 shows the elements of all alternatives at the stream crossing.

6.2.1 No Action (Alternative 1)

Under this alternative, no specific measures would be taken to address the threats to the roadway at each site. Further response would be in emergency actions only. Mitigation could be required for the resulting instream work. Currently, work is underway to excavate sediment from within the culvert and the immediate areas upstream from the inlet and downstream from the outlet (about 20 feet in either direction). Because this action is already planned, it is considered part of the "no action" alternative.

Removing sediment from these areas will increase the amount of sediment storage available in the culvert. This would be a maximum of 92 cubic yards from the culvert, and perhaps 10 cubic yards adjacent to the culvert (assuming 5 cubic yards of sediment can be removed on either end). However, sediment could very quickly fill the culvert back in, since the downstream reach (reach 4) channel bed would be higher than in the culvert. Therefore the benefits of cleaning out the culvert would likely be short lived. The culvert would function as a sediment trap. Because the sediment load is highly dependent on the number and intensity of storms in any given year, it is difficult to predict how long it would take for the culvert and channel to be backfilled. The culvert would need to be cleaned out at least annually in order to maintain sediment storage capacity. Even with regular maintenance, landslides, including a dam break flood, could overwhelm the culvert and cause ponding, even during a single storm.

6.2.2 Extensive excavation of culvert and channel (Alternative 2)

Under this alternative, heavy equipment would be used not only to remove all sediment from the culvert, but also lower the profile of the channel upstream and downstream from the culvert, and increase the channel cross-section area. To do this, access ramps would be needed on both sides of the highway. An excavator and dump trucks would be needed. The Vactor truck might also be needed to clean out the culvert because the culvert's small size precludes the use of most other equipment.

This alternative has the advantage, compared to the previous alternative, of providing significantly more sediment storage. The stream channel would be excavated 150 feet upstream from the culvert inlet, as shown in Figure 18. Excavation would take place downstream from the culvert outlet, also. The excavation would extend down to the culvert invert (about 4.5 feet) and taper to match the existing grade. The excavated channel would be about 10 feet wide with 2:1 sideslopes. In addition, the floodplain terrace that has built up around the culvert inlet would be lowered by about 2 feet. All disturbed areas other than the channel bottom would be re-vegetated. The channel would be excavated 100 feet downstream; the low spot where Reach 4 b is located (see Figure 18) could be used to increase the slope of the channel. This would require excavating the channel in the direction of the low spot and tapering to match the existing grades. Doing this could negatively affect the Copper Hill mitigation site, and new mitigation would likely be necessary.

This alternative would provide much more sediment storage than Alternative 1. The threat of catastrophic failure would be minimized in the short term. Sediment transport capacity would be increased initially, but the channel would fill up with sediment in a few years, unless re-excavated. Mitigation for the channel disturbance would also be required. Considering the area that would be disturbed, the mitigation could be substantial.

6.2.3 Concrete box culvert (Alternative 3)

Alternative 3 involves replacing the existing culvert with a larger, bottomless culvert. The new culvert would be a concrete box design, with no bottom. The culvert inlet would be set at the existing grade, as would the outlet. No significant excavation of the channel would take place, other than to place new stream sediment in the culvert. The culvert would be approximately 19 feet wide, based on 1.2 times the bankfull width of Reach 2 plus two feet, per WDFW stream simulation guidelines. The inside height of the culvert would be at least eight feet, not including stream sediment.

This alternative would require that the highway was partially or completely closed for certain periods during construction. Given the height of the embankment, much of the fill would need to be removed to be able to install the culvert. The Duvall sewer line would need to have a bypass during construction. The City has already made plans for this, in the event of an emergency under existing conditions.

This alternative would increase sediment and debris transport capacity significantly. In the event of a dam break flood upstream, sediment would be able to pass under the highway with minimal damage to the road prism. There would be more connectivity between the channel and floodplain. The stream would likely shift to Reach 4b over time, as the channel finds the low spot. There would be minimal disturbance of the floodplain upstream or downstream, and thus mitigation would be minimal.

Although the sediment transport capacity would be increased, it would not be fully restored to conditions prior to highway construction. The embankment leading up to the culvert would represent a constriction in the floodplain, and some sediment accumulation would result over time. It is difficult to predict sediment accumulation rates without a coupled hydraulic-sediment transport model, which is beyond the scope of this document. However, it can be said the amount of freeboard in the culvert would decrease somewhat over the course of ten years or more.

6.2.4 Sediment Trap (Alternative 4)

A different approach to addressing sedimentation would be to provide a large storage space on the upstream side of the highway. Sediment traps have been used for this purpose in other locations in Washington state and elsewhere. The sediment trap would be designed to have access for maintenance; the trap would need to be cleared out periodically to maintain a specified capacity. There are no good estimates of sediment load in Coe Clemmons, therefore to size a sediment trap, we used a worst-case scenario of a debris dam forming at station 11+75, filling with sediment and then releasing a dam break flood. We used the topography from the LiDAR to estimate the size of the debris dam. Under these assumptions, a sediment trap would need to have a volume of 2,200 cubic yards. To increase the factor of safety, an additional 500 cubic yards of storage was added, for a total of 2,700 cubic yards of storage. The trap would need to be an in-line trap rather than off-line, due to space limitations. The dimensions of this trap would require use of much of the floodplain in Reach 3, excavated down 4.8 feet.

The advantage of a sediment trap would be that stream crossing would not need to be re-built with a new structure. The highway would remain open, and no detours would be necessary. However, the construction of a sediment trap would have its own complications. A significant amount of stream habitat and riparian zone would be affected (about 0.4 acres), requiring mitigation. There would still be a requirement for maintenance, though it wouldn't be necessary every year.

6.2.5 Low bridge (Alternative 5)

Under this alternative, a new crossing would be built. The existing culvert and most of the embankment would be removed. A 100-foot clear span bridge would be constructed. Assuming the bridge would use pre-stressed steel girders, the low chord of the bridge would be at about 65 feet, or about 15 feet above the stream channel. The design would have to accommodate some method of attaching the sewer pipe to the bridge, and a bypass for the sewer pipe would be needed during construction. A temporary bridge would likely be necessary, as practical detour routes are very limited. Some grading of the floodplain terrace would be needed, as well as some excavation of a channel to connect the upstream and downstream reaches of Coe Clemmons Creek.

This alternative would nearly restore sediment transport capacity to pre-highway conditions. The stream would be free to meander across most of the original width of floodplain. Flood waters could overtop the stream banks and flow downvalley across the floodplain. Should a dam break event occur in Reach 2, the sediment and water discharge could pass the crossing with no effects to the highway. Though aggradation would be expected over the long-term, the stream would be able to deposit material downstream from the bridge again, accessing a very large sediment storage area. Aggradation at the stream crossing would be very small on an annual basis so would essentially be a non-issue. The riparian area upstream and at the stream crossing would be restored, and fish habitat would be improved.

Although a bridge is typically viewed as much more expensive than a culvert, considering the height of the embankment, and the excavation for the culvert, earthwork costs would not be much different.

Some incision of the floodplain terrace on the upstream side of the highway would be expected, as the stream would reestablish a more uniform gradient. This would result in a pulse of sediment downstream. This could actually improve fish habitat by replenishing Reach 4a with gravel that currently gets retained above the culvert. This alternative would allow the stream to flow to the existing low spot where Reach 4b starts. The Copper Hill mitigation area would likely be at least partially buried with sediment.

6.2.6 High bridge (Alternative 6)

This would be similar to the Alternative 5, except that the bridge chord would be higher, and the span would be longer, about 150 feet. More of the embankment would be removed, and more of the floodplain of Coe Clemmons Creek would be reconnected with the stream channel. An advantage of this alternative is that it eliminates a dip in the road of about 5 feet across the total valley. However, the high bridge could be somewhat more expensive due its length. Otherwise, the advantages and disadvantages are similar to Alternative 5.

6.3 Recommended Alternative

Alternative 6 (150-foot bridge) is the recommended alternative, due to its ability to restore most of the sediment transport capacity and provide a long-term solution to the sedimentation issue. Given likelihood of continued mass wasting upstream, and the possibility of a dam-break flood, a bridge would essentially eliminate the risk of the highway and sewer main being affected. Alternatives 3, 5, and 6 provide the best opportunities to improve sediment transport capacity and protect the highway. In consideration of the amount of construction effort involved, Alternative 6 is only somewhat more complex than alternative 3 or 5, and provides a benefit of removing a gentle dip in the highway.

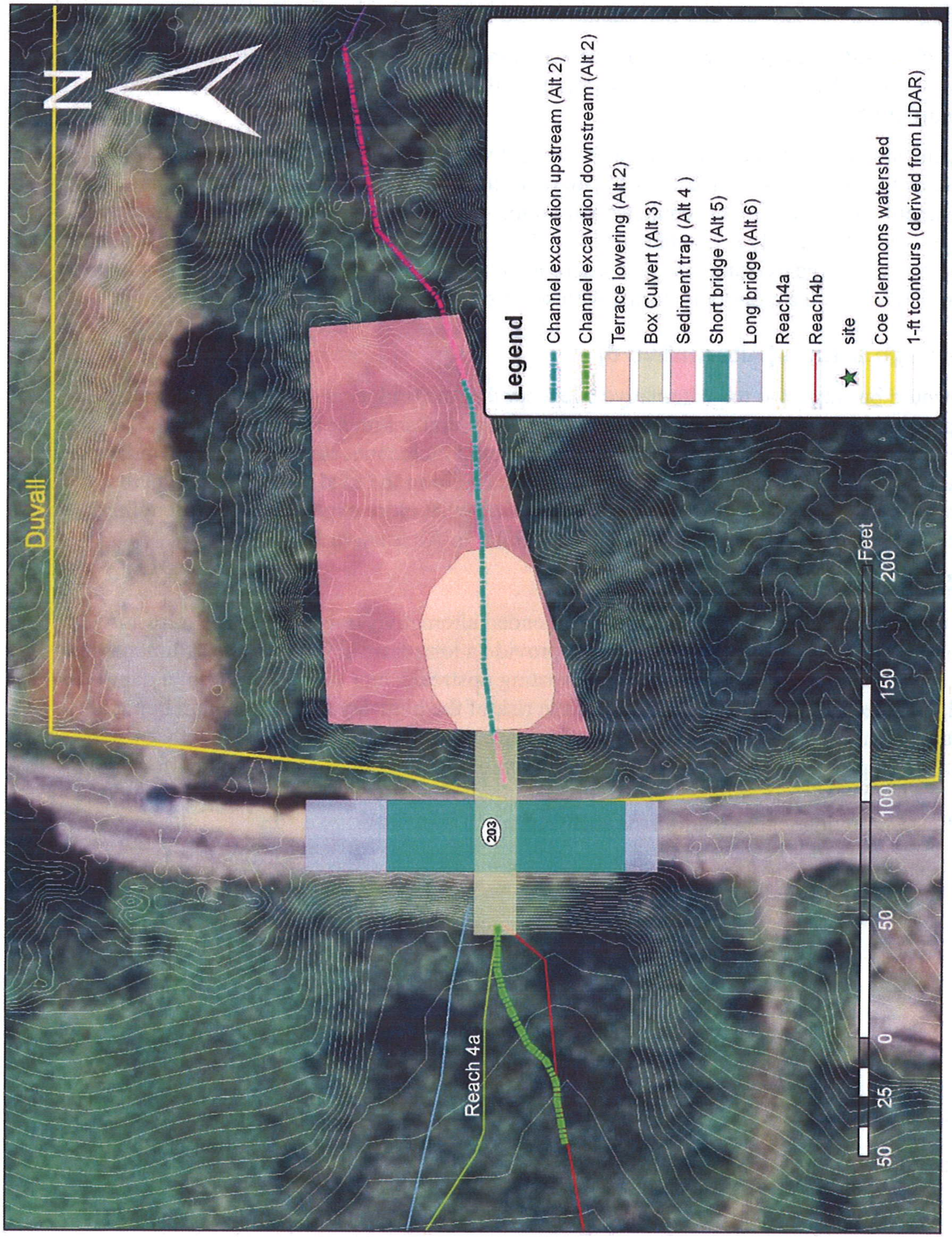

Figure 18. Schematic of the elements of alternatives considered.

Table 3. Alternative summary matrix.

Alternative	Description	Advantages	Risks	Habitat Effects	Relative Costs
No Action (Clean out sediment from culvert)	Highway configuration remains the same; periodic excavation; mitigation required. Use "Supersucker" to excavate from downstream side as far as 20 from outlet. Clean out culvert interior; clean out upstream side as much as 20 feet upstream of the inlet.	No additional permitting. Temporarily increases sediment storage in the culvert.	Continued maintenance activity; mitigation costs; Culvert can quickly be filled back with sediment. Risk for embankment failure if culvert is plugged.	Minimal.	Low (short term) Very high (long term)
Extensive clean out of culvert and channel	Build access ramps on east and west side of SR203, use heavy equipment to excavate and remove sediment from culvert and stream bottom; lower terrace surface on upstream side of culvert.	Increases sediment transport capacity of culvert; restores sediment storage potential upstream from the culvert.	Long term aggradation will eventually fill in excavated area and culvert.	Some short term loss of fish habitat.	Low
Large Box Culvert	Install new bottomless culvert with bed at existing grade.	Will increase sediment transport capacity temporarily; greatly decreases maintenance.	Long term sediment accumulation still likely	New channel habitat created; old channel will get dewatered.	High
Sediment Trap	Dredge upstream and downstream to create a large sediment basin capable of storing 50,000 cubic yards	Avoids reconstruction of stream crossing; provides sediment storage for years.	Complex, expensive permitting; maintenance commitment; liability issues	Possible stranding; removal of 0.4 acres of riparian area.	High
Low Bridge	Replace culvert with 100 foot span. Until bridge is built, keep culvert clear of sediment using vactor truck as under No Action alternative.	Provides long term solution to sedimentation; sediment transport capacity restored; sediment accumulation more downstream from highway.	Relatively complex undertaking; temporary construction impacts (traffic)	Channel & floodplain connectivity restored; fish passage restored.	High
High Bridge	Replace culvert with a 150 span bridge; eliminate dip in highway. Until bridge is built, keep culvert clear of sediment using vactor truck as under No Action alternative.	Provides long term solution to sedimentation; sediment transport capacity restored; sediment accumulation more downstream from highway; removes dip in roadway.	Relatively complex undertaking; temporary construction impacts (traffic)	Channel & floodplain connectivity restored; fish passage restored.	High

7.0 Conclusions

Where SR203 crosses Coe Clemmons Creek, its culvert has experienced a large amount of sedimentation. The culvert has less than a foot of freeboard. It is currently vulnerable to complete blockage. Blockage of the culvert could result in ponding on the upstream side of the highway embankment. This in turn could lead to catastrophic failure of the highway, through piping or overtopping and subsequent erosion. The City of Duvall sewer main located in the road prism would also fail and could spill into the Snoqualmie River.

The stream crossing is located in a naturally depositional reach, in the upper portion of the alluvial fan of Coe Clemmons Creek. Deposition occurs here because of the abrupt change in gradient as the stream leaves the hillside and enters the Snoqualmie River Valley. In addition, there are a number of recently active landslides within the ravine that are contributing sediment. There is evidence of recent incision in the stream channel; the watershed has been urbanizing rapidly; this may have caused the incision.

The best way to ensure the stability of the highway and the sewer main is to replace the culvert with a bridge. We recommend a 150-foot clear-span bridge. Construction of the bridge would involve installation of a temporary bridge, removal of much of the existing embankment, and regarding of the floodplain terrace and the stream channel where the embankment and culvert were. The new bridge would provide nearly complete restoration of sediment transport capacity, including being able to pass a dam-break flood, of which there is potential in the upstream reach.

8.0 References

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