Colony Creek
Colony Mountain Drive
Sediment Management and
Flood Protection Evaluation
Final Report

Prepared for:

Skagit County
Department of Public Works
Surface Water

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EXECUTIVE SUMMARY

Skagit County Department of Public Works is seeking a reasonable solution to reduce flooding problems along a 3200-ft long reach of Colony Creek which borders Colony Road. Sediment has nearly filled the existing channel and two seven-foot diameter CMP culverts that carry the stream under Colony Mountain Drive. As a result, water frequently overtops Colony Road forcing the County to close it to traffic. The Washington State Department of Wildlife (WDFW), the agency responsible for issuing hydraulic permits to work in streams, would like the County to implement a long term plan to minimize the need to remove sediment from the stream and thereby reduce impacts to valuable salmonid habitat. The County retained Northwest Hydraulic Consultants to evaluate conditions at the site and identify a range of alternatives to reduce flooding and the need to remove sediments from the stream.

Colony Creek will continue to transport and deposit sediment within the 3200-ft long study reach; therefore, the frequency of flooding will only get worse if something isn't done. The annual sediment deposition rate averaged over the past 50 years has been approximately 120 cu yds/year. Beaver dam outburst floods in 2002 and 2004 combined may have deposited as much as 1500 cu yds of sediment in the study reach. The outburst floods also exposed and disturbed many sediment sources along the West branch of Colony Creek, therefore, we expect sediment transport rates to remain above average for at least five years until they are stabilized by vegetation – assuming there are no more beaver dam failures. Attempting to stabilize sediment sources within the watershed is not practical; therefore, sediment management will be required within the study reach.

Alternative sediment management solutions are presented. During the course of the investigation it became clear that the project reach needed to be divided into two sections because the flooding problems are more or less independent. The first reach, which is the focus of this investigation, is a 1000-ft long reach that extends upstream and downstream from the Colony Mountain Drive crossing. For this reach, thirteen alternatives are presented and compared. The second reach is located downstream in the vicinity of two driveway bridges. Possible solutions for overtopping of Colony Road in this area are presented but additional work is needed before a preferred solution can be identified.

The thirteen alternatives presented to solve flooding problems in the vicinity of the Colony Mountain Drive crossing cover the range from simple and inexpensive (less then $20,000), to complex and costly (up to $1,500,000). Unfortunately, the inexpensive alternatives each involve removing significant quantities of material from the existing stream channel, something that WDFW has said it would rather not see. Several alternatives are presented which may store up to 50 years of sediment before channel reconstruction or significant maintenance would be required. These alternatives are relatively expensive ($500,000 +/-) and would require considerable effort. If one of these alternatives is selected, we suggest that the County consider partnering with Upper Skagit Tribe and the Skagit Fisheries Enhancement Group to seek grant funding and to possibly expand or modify the preferred alternative to include significant habitat enhancement features.

nhc does not recommend one alternative over another because they all will provide some level of relief. Rather the intent of this document is to provide the County with the information needed to consider the range of possible options, than use this information to make an informed decision as to which alternative to move forward.

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1.0 INTRODUCTION

1.1 Study Purpose

Skagit County Department of Public Works is seeking a reasonable solution to reduce persistent flooding problems along a 3200-ft reach of Colony Creek along Colony Road near Edison, Washington (Figure 1). Sediment has nearly filled the existing channel and two seven-foot diameter CMP culverts that carry the stream under Colony Mountain Drive. As a result, water frequently overtops Colony Road in several places. In response, the County frequently has to close Colony Road which cuts off the primary access route to many homes. Property owners north of the creek are also concerned because as sediment has filled the channel, the frequency and severity of flooding on their land has increased. County maintenance crews occasionally remove small quantities of sediment from the stream immediately upstream and downstream from the Colony Mountain Drive crossing; however, the benefits are short lived as sediment quickly refills the excavated areas. The Washington State Department of Wildlife (WDFW), the agency responsible for issuing hydraulic permits to work in streams, would like the County to implement a long term plan to minimize the need to remove sediment and thereby reduce impacts to valuable salmonid habitat. The County has retained Northwest Hydraulic Consultants to evaluate conditions at the site and identify a range of alternatives to reduce flooding and the need to remove sediments from the stream. This report presents the findings of **nhc**'s investigation.

1.2 Special Notes

1. The terms "left" and "right" are used in this report to refer to the "left" and "right" banks of the channel assuming that the reader is standing in the stream viewing downstream.

2. Elevations in this report are referenced to NAVD88.

2.0 BACKGROUND INFORMATION AND ANALYSIS

2.1 Stream and Road Description

Colony Creek drains a four square mile watershed located on the southern slopes of the Chuckanut Mountains in northwestern Skagit County (see Figure 2). The watershed is mainly forested, but contains a network of roads that access homes, small farms, and logged areas. Colony Creek consists of two main branches, which we will refer to at the West and East Branches. They merge to form the mainstem just before leaving the hills to flow across the historical floodplain of the Samish River. A short distance after emerging from the hills the stream encounters Colony Road (Figure 1). Here it makes a 90 degree turn northwesterly and enters the 3200-ft long constructed straight channel which is the subject of this study. Two-hundred feet downstream from the bend, the stream passes through the twin seven-foot diameter CMP culverts under Colony Mountain Drive (see Photos 1 and 2). Approximately 2600 ft and 2800 ft downstream from the culverts, the stream then passes under two driveway bridges (see Photos 4 and 5).

The capacity of the 3200-ft channel has decreased significantly because of filling with sediment. As shown in Photos 1 and 2 the culverts under Colony Mountain road are nearly full of sediment as is the channel immediately downstream (Photo 3). The bed material consists of relatively clean gravel along the first 1000-ft downstream from the culverts (Photos 3 and 6), but this changes to mucky silt at the driveway bridges because the stream slope flattens. In the past, accumulated sediment was removed from the stream to restore capacity, but this has not been done for many years. The channel is lined with mature alder trees. Spoil piles from past channel cleaning activities line portions of the right (north) bank which helps to reduce the frequency of flooding in the adjacent pasture.

2.2 Historic Alluvial Fan

An alluvial fan often forms when a stream emerges from hills and flows onto the floodplain of a larger river. At the intersection between the hills and original floodplain, the slope of the stream suddenly flattens causing sediments to deposit. Over thousands of years, these deposits tend to form a conical fan that extends onto the floodplain. An alluvial fan has developed along Colony

Creek where it leaves the hills. It is visible in Figure 3, which shows topographic relief as captured by recent LiDAR imagery collected for the County. Figure 3 reveals that the upper 1500 ft or so of the study reach is located on the distal end of this fan. As a result, the upstream portion of the study reach has a steeper slope than the lower end. The presence of an alluvial fan confirms that Colony Creek has been transporting sediment from the hills and depositing it on the historical floodplain of the Samish River for thousands of years. This will continue.

The concept of an alluvial fan is important because one alternative to manage sediment is to provide room for the stream to deposit sediment in the form of a small fan at a specific site. This will be discussed in detail later in this document.

2.3 Past Flood History

Flooding problems along Colony Creek are not new, but their frequency has increased as sediment has filled the channel. Historically, the problem was solved by removing the accumulated sediments from the channel, restoring its capacity. However, the channel has not been cleaned in many years and now it is very difficult to obtain permits to do so. As a result, the channel overtops its banks several times a year. On January 3, 2007, Pat Flanagan visited the site and observed the receding limb of a small flood (see Photos 5 to 8). This event flooded private land north of the creek and overtopped Colony Road in the three locations identified in Figure 1.

It the past five years the stream has experienced two extreme floods, both caused by beaver dam failures on the West Branch. Both beaver dams are located near the headwaters of the West Branch and impound relatively large lakes (see Figure 2). The upper lake has a surface area of approximately nine acres and the lower lake about five. The dams are about ten feet and six feet high respectively. During a major rainfall event on February 22, 2002, a section of the upper beaver dam failed, unleashing a major flood which we estimate had a peak discharge of 2000 to 2500 cfs, about five times larger than a 100-year event at Colony Mountain Drive. This discharge estimate is very rough and was computed using normal depth calculations based on high water mark and channel surveys data collected by **nhc** in a confined reach between the upper beaver dam and Lily Lake Road. For comparison, methods in the Washington State Department of Ecology Dam Safety Handbook (WSDOE, 1992) indicate that an earthen dam and

reservoir of similar size to the upper beaver lake would produce a peak discharge of about 1500 cfs during a dam break. The February 2002 flood had a significant impact on the stream. It destroyed a relatively new fish passage culvert at Lily Lake Road, ruined a small water supply reservoir concrete dam located between the lower beaver dam and Wood Road, and picked up and moved a car downstream of Wood Road.

In November 2004 the system experienced a second large flood when a section of the lower beaver dam failed. No highwater marks from this event were identified, thus its peak discharge could not be estimated. However, using tables in the WSDOE dam break manual we estimate that the peak would have been in the range of 500 to 600 cfs.

Both dam break floods had a dramatic impact on the stream. Not only was a significant amount of sediment transported to and deposited in the 3200-ft long reach along Colony Road, but numerous slopes and once stable historical stream deposits were exposed. Over time, vegetation will re-stabilize many of these sediment sources, assuming there are no future beaver dam outburst floods. However, without beaver management, future dam burst floods may occur. This will need to be considered when developing solutions to solve the flooding problems.

2.4 Field Inspection and Inventory

On January 24, 2007, Pat Flanagan and Craig Nistor of **nhc,** accompanied by Doug Couvelier of the Upper Skagit Tribe and Cris Feringer, a local resident, visited Colony Creek to examine various locations within the watershed. The majority of the day was spent inspecting the West Branch from Wood Road downstream to Colony Road to gain a better understanding of the impact of the beaver dam outburst floods and their effect on stream morphology, especially the supply, storage, and type of sediment. Notable general observations are presented below and sample photographs are included as Photos 11 to 18.

General Comments:

- The channel bed typically consists of a relatively thin layer of loose alluvial sand and gravel overlaying dense gray clay.
- The remnants of an old logging railroad are visible along portions of the mainstem and West Branch. The fill grade and track iron are visible in many locations along with several small timber bridges. It was built in the late 1800s and was referred to as the "Blanchard Logging Railroad".

- There are numerous active bank-slope failures ranging from 4 to 25-ft high which are contributing sediment to the stream. There are also numerous exposed historical alluvial stream deposits which have been reactivated by the recent extreme floods.
- There are significant quantities of large woody debris in the channel; however, the recent beaver dam floods left a lot of LWD lying on top of the stream banks. Therefore, it does interact with the flow and thus does not provide significant salmonid habitat.
- In the vicinity of the apex of the historical alluvial fan, about 400 ft upstream from the study reach, the stream bed is covered by a very healthy mix of course gravel which creates some of the best spawning habitat in the basin.

2.5 Stream Surveys

On December 11th and 12th 2006, Pat Flanagan and Chris Frei of **nhc** traveled to the project site and collected the survey data described below.

- Fourteen cross sections were surveyed along the stream channel at the locations identified in Figure 4.
- Stream bed thalweg and water surface profiles were surveyed over a 3600-ft long reach starting about 3000 ft downstream from Colony Mountain Drive and extending approximately 600 ft upstream. As shown in Figure 5, the slope of the stream bed gradually increases moving upstream, from effectively flat at the downstream end to 0.008 upstream.

2.6 Hydrology

No stream flow gaging records are available for Colony Creek or any similar neighboring streams. For a previous restoration project on McElroy Slough, an HSPF computer model of the Colony Creek watershed was created (MWG, 2005). Colony Creek empties into McElroy Slough about two miles downstream from Colony Mountain Drive. HSPF is a hydrologic computer model which can be used to create a synthetic record of historical stream flows for a stream (EPA, 1993). **nhc** updated the HSPF model to include current land-use conditions, then used it to estimate historical annual instantaneous peaks for Colony Creek for the past 150 years using recorded rainfall data. A statistical flood frequency analysis was then performed on the annual peaks to estimate the flood quantiles at the two sites listed in Table 1. The sites are at Colony Mountain Drive and the on West Branch near the lower beaver dam. The extreme beaver dam outburst floods were not included in the data set that was used in this analysis. Given the assumption of no extreme beaver dam floods, we believe that values presented in Table 1 are otherwise slightly conservative, but there is enough uncertainty in the hydrology of the watershed that we believe it prudent to use conservative discharges for design.

2.7 Stream Hydraulics -- HEC-RAS Model Development

Hydraulic analyses of the site were performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) which is a commonly used computer program developed by the United States Army Corps of Engineers (USCOE, 2005). The model was used mainly to evaluate the hydraulic performance of the proposed alternatives. This will be discussed in detail in a later section. Although it was used to evaluate hydraulic characteristics of the existing system, it does not take a model to recognize that the channel and culverts are so full of sediment that they can not even carry an annual flood before water begins to inundate neighboring properties and Colony Road.

To create an HEC-RAS model, the user must input certain types of data that describe the characteristics of the stream channel, floodplain, and any constructed features such as road fills and culverts. The geometry of the stream channel and floodplain are represented in the model by the 14 cross sections identified in Figure 4 plus several interpolated cross sections which were developed from the survey sections. The channel portion of each cross section represents conditions that were surveyed in December 2006. The floodplain extensions were taken from the topographic LiDAR data supplied by the County. Culvert and road geometries were obtained from the survey conducted by **nhc**.

Roughness coefficients (as represented by Manning's n) must be added to the model to identify the conveyance characteristics of each cross section. These coefficients were estimated using engineering judgment and reference to classical publications (Chow 1959, Barnes 1987). In general, the stream channel is represented by an n value of 0.055 and the overbank floodplain by a range from 0.06 to 0.08.

For each simulated water surface profile, the user must input a starting water surface elevation at the downstream extent of the model or, as an alternative, let the computer estimate it. For Colony Creek, the computer model was allowed to compute this elevation using normal depth procedures based upon an estimated energy slope that is nearly flat. Based upon field observations during the January 3 flood, water moves very slowly at the downstream end of the study reach because there is little to no slope between the driveway bridges and the reach downstream that was recently restored.

2.8 Sediment Transport and Deposition

It is difficult to predict with certainty the quantity of sediment that will be delivered to and deposited within the study reach and the culverts under Colony Mountain Road. Empirical sediment transport equations can produce estimates that vary by an order of magnitude. At this site, it is our opinion that the most meaningful estimate of future sediment deposition rates can be determined by estimating the volume of material that has been deposited within this reach since the channel was last cleaned. According to Beverly Macken, the owner of the land north of the stream immediately downstream from Colony Mountain Drive, we can draw the following conclusions:

- The 3200-ft long channel that is the subject of this investigation was last cleaned in the early 1980s. Prior to that, it was cleaned in the late 1950s or early 1960s.
- After it was cleaned, the channel was 4 to 5 feet deep.
- Prior to the 2002 beaver dam outburst flood, about two feet of sediment filled the bottom of both culverts under Colony Mountain Road and flooding was not a frequent problem.
- Even relatively small floods now inundate her pasture and overtop Colony Road.

Based upon these comments and using the survey data collected for this investigation we have estimated that between the early 1980s and present (say 25 years), approximately 3000 cu yds of sediment were deposited within project reach. We can also assume that between the late 1950s and the early 1980s (say 25 years) about the same amount of sediment (3000 cu yds) was deposited. Based upon these volumes the average annual volume of sediment deposited during this 50 (+/-) year period was roughly 120 cu yds/year.

Based upon Mrs. Macken's observations, we know the beaver dam outburst floods deposited a significant amount of sediment within the reach. It may have been as much as one-half of the total sediment volume, 1500 cu yds. We do not know how much sediment was deposited by each beaver dam flood, but we believe the first flood was probably three to four times the size of the second. Therefore, keeping with this ratio, a reasonable estimate would be to assume that the first flood deposited up to 1000 cu yds and the second 500 cu yds.

Although these estimates are very rough, they do provide valuable information which can be

used to help evaluate the effective life of each alternative. Therefore, we will make the following assumptions when we estimate the amount of sediment that can accumulate in the channel before the capacity of the alternative is reduced to the point that flooding once again becomes a frequent problem along the project reach:

1. Sediment will be allowed to accumulate in the channel until the capacity of the culvert crossing at Colony Mountain Drive and the channel upstream and downstream is reduced to about a 10-year flood.
2. For the first 5 years we will assume that 180 cu yds / year of material will deposit within the study reach – 150% of the average rate over the past 50 years. We expect sediment transport rates to remain above average for at least five years until many of the sources that were exposed by the beaver dam floods are stabilized by vegetation. This assumes that no beaver dam outburst floods occur during this period.
3. Beyond 5 years we will assume that 120 cu yds / year will deposit – the estimate of the average rate over the past 50 years.
4. If a beaver dam outburst flood occurs we will assume that 750 cu yds will be deposited. This is the average of the estimates for the two past events.

3.0 STRATEGIES AND ALTERNATIVES

As requested by the County, **nhc** developed and considered a suite of alternatives to manage the sediment problems at the Colony Mountain Drive crossing and along Colony Road. These are described in the sections below. Management of sediment sources in the Colony Creek watershed upstream from the crossing is not practical or feasible for Skagit County, due to the large number and remote locations of the slope failures and active bank erosion sites. Instead, the only realistic strategy is to focus on managing sediment deposition and transport in the vicinity of the crossing. Strategies might include removing deposited sediment from the existing channel and culverts, replacing the culverts, removing existing earthen access road fills and berms in the pasture bordering the channel, or sediment trapping in a constructed alluvial fan or basin. The following subsections describe these strategies and present 13 alternatives that combine these treatments to improve conditions at the crossing and along the road.

3.1 Colony Mountain Road Crossing

The following options were considered for the Colony Mountain Drive Crossing:

- ***Leave the existing culverts***
  This alone would amount to the "do nothing" alternative.

- ***Abandon the crossing and excavate an open channel through the road fill***
  The existing culverts would be removed, and replaced with an excavated open channel. The intersection of Colony Mountain Drive and Colony Road would be eliminated. This alternative was not pursued, because it is our understanding that it would unacceptable to abandon the crossing.

- ***Replace the existing culverts with a new concrete box culvert at same location***
  The existing culverts would be removed and replaced with a single 8-ft high (or 14-ft for Alternatives 3B and 3C) by 20-ft wide concrete box culvert designed to meet Washington State Department of Fish and Wildlife fish passage requirements. The new culvert would be constructed at the same location as the existing culverts. A culvert width of 20-ft appears to be about the size the WDFW will require, but this will need to be confirmed through discussions and possibly a field visit with WDFW personnel.

- ***Replace the existing culverts with a new concrete box culvert and move crossing northeast***
  The existing culverts would be removed and replaced with a single 8-ft high by 20-ft wide concrete box culvert. The new culvert would be located 45 ft northeast of the current crossing. Relocating the culvert would move the stream away from Colony Road and provide more space downstream for the stream to expand and deposit sediment.

- ***Construct a new culvert under Colony Road and remove the existing culverts***
  The existing culverts under Colony Mountain Drive would be removed and replaced with a single 10-ft high by 20-ft wide concrete box culvert under Colony Road. A new channel would be constructed along the northern edge of the existing blueberry field and a second 20-ft wide culvert would be installed under Colony Road near the railroad to reconnect the stream to the restored downstream reach.

3.2 Channel Modifications or Re-Construction

- ***Channel Sediment Removal***
  The stream channel downstream from the crossing would be re-constructed to increase sediment storage and hydraulic capacity. Two options are considered: 1) re-construction of the first 500-ft of the channel immediately downstream from Colony Mountain Drive. 2) re-construction of the entire 3000-ft of channel along Colony Road downstream from Colony Mountain Drive. This would increase channel capacity along the reach and thus reduce the frequency of overbank flooding. However, cleaning the channel at the downstream end of the reach in the vicinity of the two driveway bridges will have limited benefit. In this area the slope of the steam is so flat that flood levels are controlled by water levels in the newly restored reach immediately downstream. Therefore, digging a deeper channel in the vicinity of the driveway bridges will have little benefit.

- ***Channel Relocation and Construction***
  Moving the culvert 45 feet northeast will require purchasing approximately two acres of the pasture downstream from the road. A new channel would be constructed that connects the new culvert outlet to the existing stream channel. For this option we have assumed that a low set-back berm would be constructed north of the new channel to mitigate the potential for increased flooding on the downstream pasture and wetland. However, this berm may be difficult to permit because it passes through an established wetland. It could be left out of the design, but the County would need to consider the potential increased flooding and sedimentation impacts to the downstream pasture and wetland.

- ***Removal of Spoil Pile Berm and Field Access Road***
  Downstream from Colony Mountain Drive, sections of the right (northeast) side of the stream are bordered by a 1 to 2 ft high earthen berm that appears to be spoils from past channel cleaning. Alder trees of varying ages are growing on the berm. In addition, landward of this, there is an earthen fill road that provides access into the pasture. Removing all or portions of this berm and the road would allow flood water to expand and spread out across the pasture which would reduce flood levels along this section of the stream. Even more important, however, it would lower water levels at the outlet of the culvert which will increase the capacity of the crossing.

3.3 Sediment Storage or Trapping

- ***Artificial Alluvial Fan Downstream from Crossing***
  The goal of this alternative is to create a large open area downstream from Colony Mountain Drive (or for Alternative 5 downstream from Colony Road) where the stream can spread out

and deposit sediment. Sediment would gradually accumulate in this area in the shape of an alluvial fan.

- ***Sediment Trap or Collection Area Upstream from Crossing***
  A sediment collection area would be constructed approximately 300-ft upstream from Colony Mountain Drive in an existing field. It could be either a classic sediment detention basin or an over-excavated low flat floodplain area that would collect sediment in the form of a small alluvial fan. The concepts, which are presented in Figures 16 and 17, both maximize the available storage area which in-turn reduces the need for maintenance. The sediment basin will hold 1500 to 2000 cu yds and the collection area 500 to 750 cu yds. Smaller versions of either option could be installed. Both of these options will require periodic sediment removals if they are to provide sediment relief.

3.4 Other Features and Activities

- ***Place Fill in Low Spots along Colony Road Downstream and Construct a Low Berm Upstream***
  As identified in Figure 1, flood water overtops Colony Road both upstream and downstream from Colony Mountain Drive. Filling in several low spots along Colony Road downstream from the culverts with up to six inches of material would greatly reduce the frequency of flooding as would placing a low earthen berm (< 1.5 feet high) between the road and channel upstream from the culverts. These improvements may cause flood levels to rise slightly on private property north of the stream. However, upstream from Colony Mountain Drive the right (northeast) bank rises quickly thus this shouldn't be a problem. Downstream from Colony Mountain road there may be a slight increase in flood levels in the pasture.

- ***Beaver Management***
  As long as the large beaver dams and lakes remain in the upper watershed, there will be the potential for future dam break outburst floods. This alternative would involve some form of beaver management, aimed at either limiting the size of the beaver dams and thereby the volume of water in the lakes or eliminating the beavers altogether.

3.5 Thirteen Alternatives to Solve Flooding Problems in Vicinity of Colony Mountain Drive

Thirteen alternative concepts have been created by combining the strategies described in the preceding sections. These alternatives address the flooding problems in the vicinity of the Colony Mountain Drive. These alternatives do not address problems near the downstream end of the study reach because the flooding is generally independent of what occurs in the vicinity of Colony Mountain Drive. That said, increasing the capacity of the culvert crossing and eliminating the overtopping of Colony Road in the vicinity of Colony Mountain Drive, will send more water downstream which may increase flood levels slightly in the vicinity of the driveway bridges. Concepts to solve flooding problems in the vicinity of the driveway bridges will be

discussed later in this report.

The alternatives to solve flooding problems in the vicinity of Colony Mountain Drive are summarized in Table 2. The table provides a preliminary screening of the alternatives based on sediment management requirements, potential environmental impacts, and expected construction costs. The stated costs are *very rough* "ballpark" estimates which are based solely upon the personal experience of the authors of this report. The primary intent of these estimates is to provide the County not only with an rough idea of what each alternative may cost, but more importan provide a way to compare the alternatives. Detailed cost estimates have not been prepared. An assessment of the overall ranking for each alternative is provided in the rightmost column of the table. A brief written description of each alternative follows:

Alternative 1 – Do Nothing (No Figure)

Just as the title implies, this alternative would leave conditions as they are. The County would continue to annually remove a small amount of material from the channel immediately upstream and downstream from the crossing. Unfortunately, this excavated "hole" will quickly fill with sediment and plug the culverts. This alternative does nothing to reduce flooding along the 3200-ft project reach.

General Comments Regarding Alternatives 2, 3, and 4

Within the 1000-ft reach that is the subject of the alternatives presented below, there are two features common to all solutions. Downstream from the crossing there are several low spots along the right edge of Colony Road where water tends to flow over the road. At a minimum these low spots will need to be raised. It appears this will typically only require a few inches of fill, possibly up to a maximum of about six inches. Upstream from Colony Mountain Drive each alternative includes a one-ft to 1.5 foot high berm between the road and the channel. It is our opinion that these improvements have to be installed if any of the alternatives are going to have a reasonable effective life, requiring little or no maintenance.

Alternative 2A – Excavate and Restore Existing Channel 500-ft Downstream (Figure 6)

The key to keeping the existing culverts open is to lower the stream bed downstream. The stream bed must be lowered so that transported bedload entering the crossing can pass freely downstream. To eliminate any form of obstruction within the stream bed, about 500-ft of the downstream channel will need to be restored. This would require removing approximately 500 cu yds of sediment. Immediately following construction, the crossing and channel will just pass the 25-year flood without overtopping Colony Road. After about 1 to 2 years, sufficient sediment will have accumulated in the channel so that the 10-year flood will begin to overtop Colony Road.

Alternative 2B – Excavate and Restore Existing Channel 500-ft Downstream Plus Remove Sections of the Spoil Pile Berm and Field Access Road (Figure 7)

This alternative is identical to 2A, but it includes removing sections of the spoil pile berm and field access road on the right bank. This will allow water to spread out in the pasture which will lower water levels at the outlet of the culvert. As noted, previously, lowering the "tailwater" elevation at the outlet of a culvert will increase culvert capacity. Immediately following construction, the crossing and channel will just pass the 25-year flood without overtopping Colony Road. After about two years, sufficient sediment will have accumulated in the channel so that the 10-year flood will begin to overtop Colony Road.

Alternatives 2C – Excavate and Restore Existing Channel 3000-ft Downstream Plus Remove Sections of the Spoil Pile Berm and Field Access Road (Figure 8)

Alternative 2C is identical to 2B, except the entire channel downstream from the crossing (about 3000 feet) would be restored. This would require the removal of approximately 3000 cu yds of material. Immediately following construction, the crossing and channel will just pass the 100-year flood without overtopping Colony Road. After 10 to 12 years, sufficient sediment will have accumulated in the channel so that the 10-year flood will begin to overtop Colony Road.

Alternatives 3A, 3B, 3C – Replace Existing Culverts with a New Culvert in Same Location (Figures 9, 10, and 11)

The existing culverts would be removed and replaced with a new 8-ft (14-ft for 3B and 3C) high by 20-ft wide by 60 feet long concrete box culvert. To increase capacity, the low chord of the culvert would be placed at elevation 21 ft NAVD, about 2.5 ft higher then the top of the existing culverts. Each alternative is combined with the following channel modifications:

- Alternative 3A -- includes only minor regarding of the stream bed immediately upstream and downstream from the culvert.
- Alternative 3B -- includes restoring 500-ft of the downstream channel and removing the spoil pile berm along the right (north) bank.
- Alternative 3C -- includes restoring 3000-ft of the downstream channel and removing the spoil pile berm along the right (north) bank.

For Alternative 3A, 3B, and 3C, immediately following construction, the crossing and channel will just pass the 2-year, 25-year, and 100-year flood without overtopping Colony Road respectively. After 0 years, 5 to 7 years, and 20 to 25 years respectively, sufficient sediment will have accumulated in the channel so that the 10-year flood will begin to overtop Colony Road respectively.

Alternatives 4A, 4B, and 4C – Replace Existing Culverts with a New Culvert and Move Crossing North (Figures 12, 13, and 14)

The existing culverts would be removed and replaced with a new 8-ft high by 20-ft wide by 80-feet long concrete box, but unlike 3A, 3B, and 3C, the new crossing would be relocated approximately 45 feet northeast. All three alternatives would include excavating a new 650-ft long channel downstream to connect to the existing stream. A low earthen berm would also be constructed north of the reconstructed channel to limit flooding within the downstream wetland and pasture. Alternative 4B would also include excavating part of the downstream pasture to

create a low flat wide area where sediment would collect in the form of a small alluvial fan. Alternative 4C is the same as 4B but also includes restoring the remainder of the existing stream channel downstream to the driveway bridges.

For Alternative 4A, 4B, and 4C, immediately following construction, all three alternatives will just pass the 25-year flood without overtopping Colony Road. After 15 to 20 years, 30 to 45 years, and 30 to 50 years, sufficient sediment will have accumulated in the channel and on the floodplain so that the 10-year flood will begin to overtop Colony Road respectively.

Alternative 5 – Redirect Colony Creek under Colony Road (Figure 15)

This alternative would eliminate the existing crossing and replace it with a new crossing under Colony Road. The new culvert would be an 8-ft high by 20-ft wide by 80-ft long box. A new channel would be excavated downstream and a new culvert 8-ft high by 20-ft wide by 70-ft long box would need to be constructed under Colony Road near the railroad to reconnect the stream to the downstream channel. There is an existing small culvert under the road near the railroad, but it would not have the required capacity nor would it meet fish passage requirements. The land immediately downstream from the new crossing would be lowered to allow sediment to deposit in the form of a small alluvial fan. Colony Road near the driveway bridges may still need to be raised slightly to prevent water from flowing to the north over the road.

For Alternative 5, immediately following construction, the crossing and channel will just pass the 25-year flood without overtopping Colony Road. After 30 to 50 years, sufficient sediment will have accumulated in the channel and on the floodplain downstream so that the 10-year flood will begin to overtop Colony Road.

Alternative 6A and 6B – Upstream Sediment Collection Area (Figures 16 and 17)

Sediment traps require periodic in-stream sediment removals and thus are not desired by WDFW, but from a cost and maintenance perspective, the County may find these very attractive. Two options are presented here. A conventional sediment basin is shown in Figure 16 which will store approximately 1500 to 2000 cu yds. Assuming the sediment deposition rate is 180 cu yds / year for the first five years and 120 cu/years thereafter, the basin would be full in 10 to 12 years. The sediment basin could be made smaller to make it easier for County maintenance crews to maintain it on a regular cycle. An alternative would be to construct a small alluvial fan type sediment collection area such as the one shown in Figure 17. This would hold 500 to 750 cu yds and would be full in 3 to 5 years – all of this assuming there isn't another beaver dam outburst flood during this time.

Alone, neither alternative will solve the current flooding problems at the Colony Mountain Road crossing. At a minimum they would need to be combined with a "*one-time*" cleaning of the downstream channel such as is presented in Alternatives 2A, 2B, or 2C or they could be easily combined with Alternatives 3 through 5. These collection areas could be overwhelmed by the volume of sediment transported by a future beaver dam outburst flood. If this occurred, the collection area would need to be cleaned following the event and there minor sediment removals may be required from the downstream channel, depending upon the severity of the deposition.

Optional – Beaver Management

If the County is going to invest a significant sum of money into capital improvements at this site, then Beaver management should be considered. If beaver dam outburst floods can be prevented, then we can predict with relative confidence the effective life of these alternatives. On-the-other-hand if a Beaver Dam flood occurs, the improvements could be quickly overwhelmed with sediment, rendering the improvements ineffective.

3.6 Discussion of Possible Alternatives to Solve Flooding Problems in Vicinity of Driveway Bridges

The flooding problem along Colony Road near the two downstream driveway bridges can not be solved solely by cleaning the channel in the vicinity of the crossings. Flood levels here are mainly controlled by what is happening in the reach downstream, not by the sediment that has accumulated in the channel in the vicinity of the bridges. Something in the downstream reach is causing water to back up and pond in the vicinity of the two driveway bridges. During floods, this frequently causes water to overtopping Colony Road during floods. Although we do not what the cause is, we suspect that the slope of the stream and floodplain in the restored reach downstream are so flat that water slows and ponds in the vicinity of the two driveway bridges. The key to lowering flood levels in the vicinity of the driveway bridges will to see if there are improvements that can be made in the downstream restored reach that will increase conveyance and thus stop the ponding. We do not know if this is possible or what type of improvements might be needed. We would first need to obtain and review the hydraulic analysis that would have been completed for the restoration design project, assuming it exists. This should help us identify the features that are causing the water to pond and should allow us to determine if there practical solutions. The focus of the current project is to identify possible solutions to solve flooding problems upstream in the vicinity of the Colony Mountain Drive. We had hoped to be able to also identify a reasonable solution for the overtopping of Colony Road near the driveway bridges, but it is clear this will require additional effort. That said, we offer the following possible solutions for consideration.

- **Construct Conveyance Improvements within Downstream Restored Reach**
  As noted above, we do not know what or if improvements are possible without further investigation.

- **Raise Colony Road or Construct a Low Berm between the Road and Stream**
  This would be the most logical solution, but it may increase flood levels north of the stream and thus may not be acceptable to the residents. We suspect that any increase in water levels would only be a few inches because flood water appears to be free to spread out across a relatively large floodplain to the north. However, to determine the height of this impact

would require computer modeling. If it can be shown that the impact of raising the road or building a berm is relatively small, then maybe it can be combined with simple flood protection features for the residents to the north. For example, minor regrading of land surrounding structures.

- **Raise Colony Road and Install High-Flow Bypass Culvert Under the Road**
  Culverts would be installed under Colony Road and the road would be raised. We envision a culvert opening that is one to two feet high and 40 to 60 ft long. The exact size would need to be determined using the computer model mentioned above.

- **Move the Stream Away from Road and Restore the Stream**
  This alternative would involve relocating and restoring the stream north of the existing residents. A low earthen berm would be constructed along the southern edge of the new stream / floodplain corridor to prevent water from flooding the homes and road. A new crossing may need to be installed in the existing driveway that extends across the floodplain. This would be a large project, but one in which the County could partner with the Upper Skagit Tribe and/or the Skagit Fisheries Enhancement Group to expand the solution to include significant stream restoration and habitat improvements.

- **Alternative 5 (Described in preceding section)**
  It is possible that Alternative 5 described previously may prevent water from overtopping Colony Road if water levels on the south side of the road remain below the road surface. Unfortunately, we do not know if water levels south of the road will extend high enough to overtop Colony Road. This would require careful consideration of flood volumes, storage, flow conditions, etc. which is beyond the scope of this investigation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Colony Creek will continue to transport and deposit sediment within the 3200-ft long study reach. Annual sediment transport rates are likely to remain above average for at least five years, until vegetation can re-establish itself on many of the alluvial sediment sources that were exposed by recent beaver dam outburst floods. If a beaver dam flood occurs, it could deliver and deposit greater than ten times the average annual sediment load to the study reach. Attempting to stabilize sediment sources within the watershed is not practical; therefore, sediment management will be required within the study reach.

Alternative sediment management solutions have been presented. They cover the range of reasonable concepts, from simple and inexpensive to complex and costly. The solution that is ultimately implemented will have to be negotiated with WDFW. To this end we offer the following comments.

To solve many of the flooding problems at minimal cost, Alternative 2B combined with an upstream sediment collection area would be seem to be the most reasonable. However, WDFW will resist this alternative because it essentially is the channel dredging solution that they have strongly opposed and it would require periodic removal of sediment from the upstream sediment basin or collection area. It also leaves in place the two CMP culverts that they believe should be replaced.

Replacing the existing culverts with a new larger culvert that is designed to meet WDFW fish passage requirements would be well received by WDFW; thus, they may be willing to consider Alternative 3C which has a 20 to 25 year effective life. Again, their greatest concern will be impacts associated with removing sediment from the existing channel.

The County may wish to consider either Alternative 4B or 4C. These, however, require a number of potentially costly actions which include purchasing land or obtaining a conservation easement from the Mackens, owners of the pasture, and the construction of a new channel and possibly sediment collection area. Both alternatives would have long effective life of more than

30 years – assuming no beaver dam outburst floods. Even if an outburst flood occurs, these alternatives have ample sediment storage room to accommodate such an event.

We do not see the advantage of Alternative 5 over Alternative 4B or 4C unless the Mackens decide not to work with the County. One advantage of Alternative 5 is that it may reduce overtopping of Colony Road downstream near the two driveway bridges without impacting the property owners north of the stream.

Alternatives 6A and 6B are practical and cost effective, but WDFW will resist them. Alone they will not solve the problem at Colony Mountain Road and thus would need to be combined with one of the other alternatives.

Several options have been provided that may prevent water from overtopping Colony Road near the driveway bridges. However, additional investigations are needed before a preferred alternative can be identified.

If one of the more costly alternatives is selected, we suggest that the County consider partnering with the Upper Skagit Tribe and the Skagit Fisheries Enhancement Group to seek grant funding and to expand or modify the alternative to include significant habitat enhancement features.

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