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KPFF Consulting Engineers
1601 5th Ave #1600
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Attention: Anne Fabrello-Streufert, Project Manager (KPFF)
Via email: Anne.Fabrello-Streufert@kpff.com

Re: **Mill Creek at South Skagit Highway Phase 1 Design**
Geomorphic Summary

Dear Ms. Fabrello-Streufert:

NHC is assisting KPFF with the preliminary design of a reroute of the South Skagit Highway to cross Mill and Savage Creeks at more favorable locations away from an area of complex alluvial fan-floodplain interaction that has led to a poor level of service and high maintenance burden at those crossings (Figure 1). NHC is providing Hydrologic, Hydraulic, and Geomorphic analysis to support this design. Section 1 of this technical memo outlines key observations supporting the decision to move Mill Creek Bridge out of the zone of aggradation. The realigned road will also result in moving the crossing location over Savage Creek and removal of the South Skagit Highway embankment that affects wetlands and constrains hydraulic and geomorphic processes across approximately 100 acres of Skagit River Floodplain.

1 MILL CREEK SITE GEOMORPHIC HISTORY

Rapid accumulation of sediment in Mill Creek at and downstream of the South Skagit Highway crossing has almost completely filled the bridge opening over the past four decades (Figure 1). This accumulation has resulted from interaction between channel changes in the Skagit River and high sediment supply from Mill Creek. Understanding this history will help guide the prediction of future channel change, understanding of possible future flood scenarios, and determinations about preferred crossing locations.

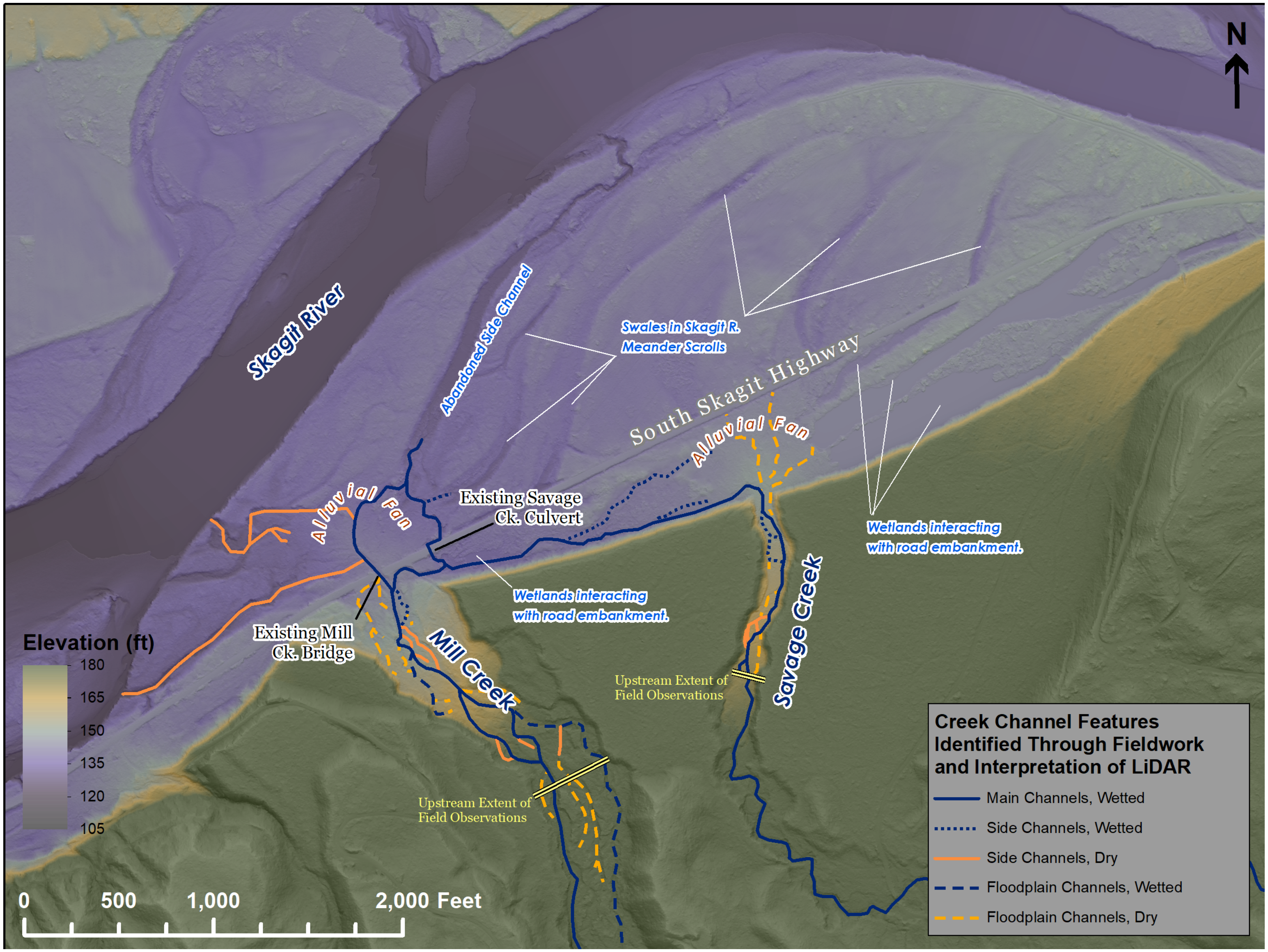

Figure 1: Overview map of Mill and Savage Creeks and Skagit River Floodplain between the creek fans and river

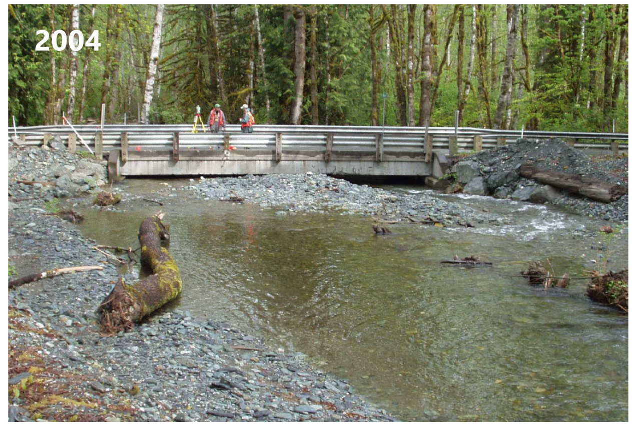

Figure 2: Photos of the Mill Creek Crossing between 1972 and 2024. 1972 to 2004 photos from NHC (2004).

1.1 Mill Creek Interactions with Skagit River

Aerial photos of the site in 1972 (Figure 2) show that a large (~150 ft wide) side channel of the Skagit River meandered to a position about 240 ft northwest of the Mill Creek crossing location and that Mill Creek had built a small delta-fan bar into this side channel. Before this time, periodic high flows in the Skagit River likely transported most of the sediment supplied by Mill Creek out of this side channel, keeping it open. Between 1972 and 1985, however, the slow accumulation of sediment at the mouth of Mill Creek reduced the capacity of flow through the side channel to carry away sediment supplied by Mill Creek, creating a positive feedback cycle where sediment accumulation reduced the amount of flow through the side channel, further driving additional sediment accumulation. By 1985, the Mill Creek delta-fan had prograded completely across the side channel and blocked throughflow from the Skagit River (Figure 2). After this, all the sediment supplied by Mill Creek was deposited locally and Mill Creek began building a larger alluvial fan through a sequence of avulsions downstream of the South Skagit Highway, driving aggradation of the bed at the crossing.

This sequence explains the history of aggradation at the Mill Creek crossing. Substantial aggradation began around 1985, when the side channel closed, and aggradation thereafter proceeded rapidly until the 1990s, after which periodic sediment removals were necessary to maintain flow through the bridge.

Comparison of recent (2017-2023) shows that sediment accumulation remains focused on the Mill Creek fan near and downstream of the crossing, with little channel profile change occurring from above about 600 ft upstream of the current crossing. The proposed Mill Creek bridge will be located upstream of this aggradation zone.

Upstream of this aggradation zone, Mill Creek has an anabranching planform with numerous side channels and floodplain channels. The creek is locally perched above the valley bottom, and avulsions into any of these channel features may occur.

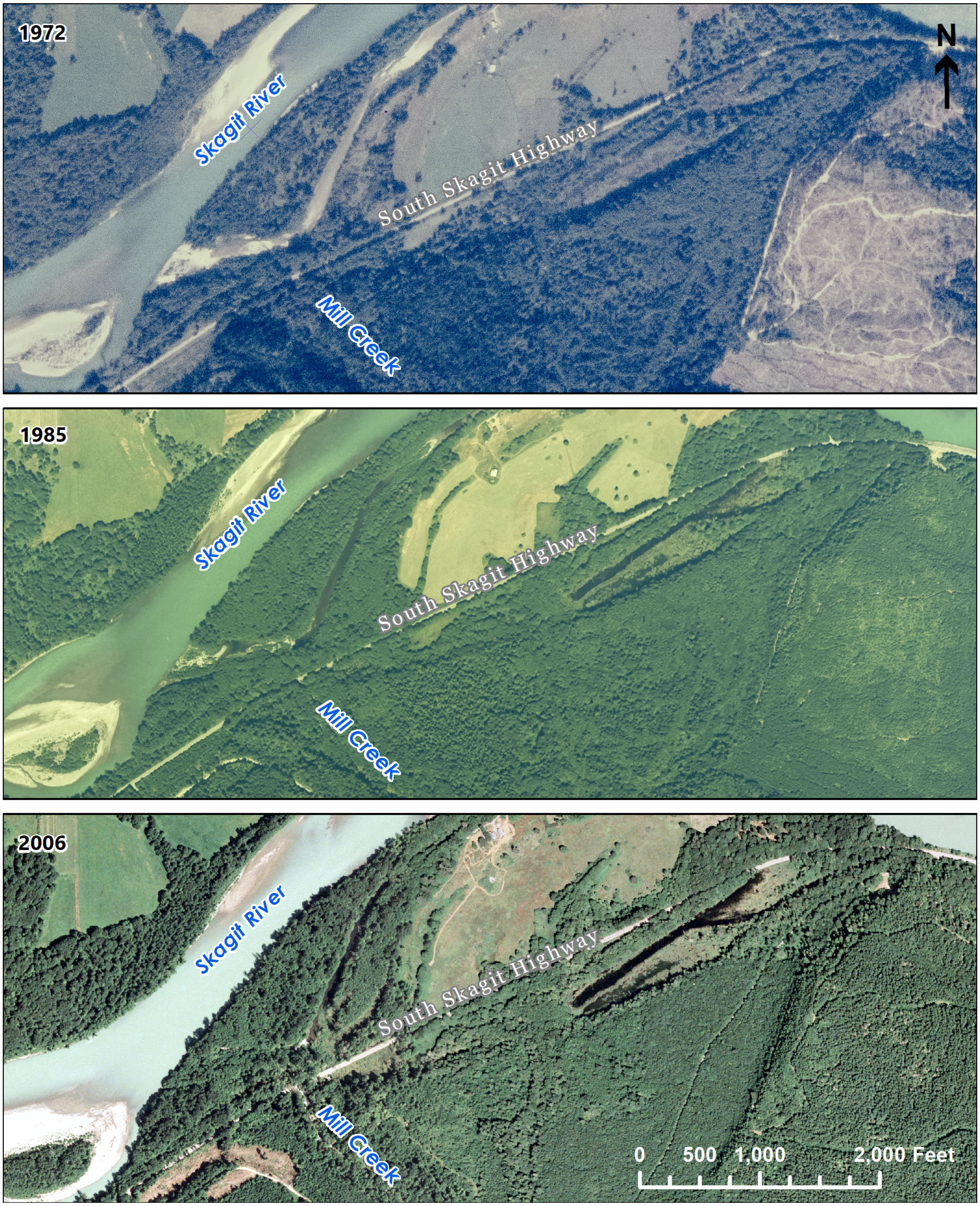

Figure 3: Aerial photos showing closure of the Skagit River side channel at Mill Creek confluence.

1.2 2002 Hydrogeomorphic Flood

A particularly important flood occurred in 2002, when a rain-on-snow flood generated numerous landslides throughout the Mill Creek Basin which introduced a large volume of sediment and large wood to the creek and generated a combined debris flow and bridge-dam failure outburst flood (Grizzel, 2002). In addition to supplying sediment to the South Skagit Highway Crossing over the creek, wood entrained by the flood formed very large jams across the creek upstream of the crossing (Grizzel 2002; Figure 3). Because debris flows move faster than flood waves and entrain material from along their paths, the peak discharges in such events can be much higher than typical hydrometeorological floods (Jakob et al., 2015) and the combined effects of the wood jams and large flood peak raised water levels enough to scour channels through terraces well above the channel elevation (Grizzel, 2002). Preliminary estimates indicate that the peak discharge of the 2002 event was potentially an order of magnitude higher than the estimated 100-year recurrence interval flood generated solely from hydrometeorological processes. Field observations from 2024 and interpretation of LiDAR show this terrace (the T1 terrace on the right bank between RM 0.45 and 0.8 in Figure 3) was located at an elevation of six to eight feet above the channel. Published observations of the event do not include estimates of the debris flow volume or peak instantaneous discharge; however, using a hydraulic model and quantitative calculations, we estimate discharge could have been bout 8,000 cfs ± 5,000 cfs. The proposed bridge will be designed to withstand such a discharge.

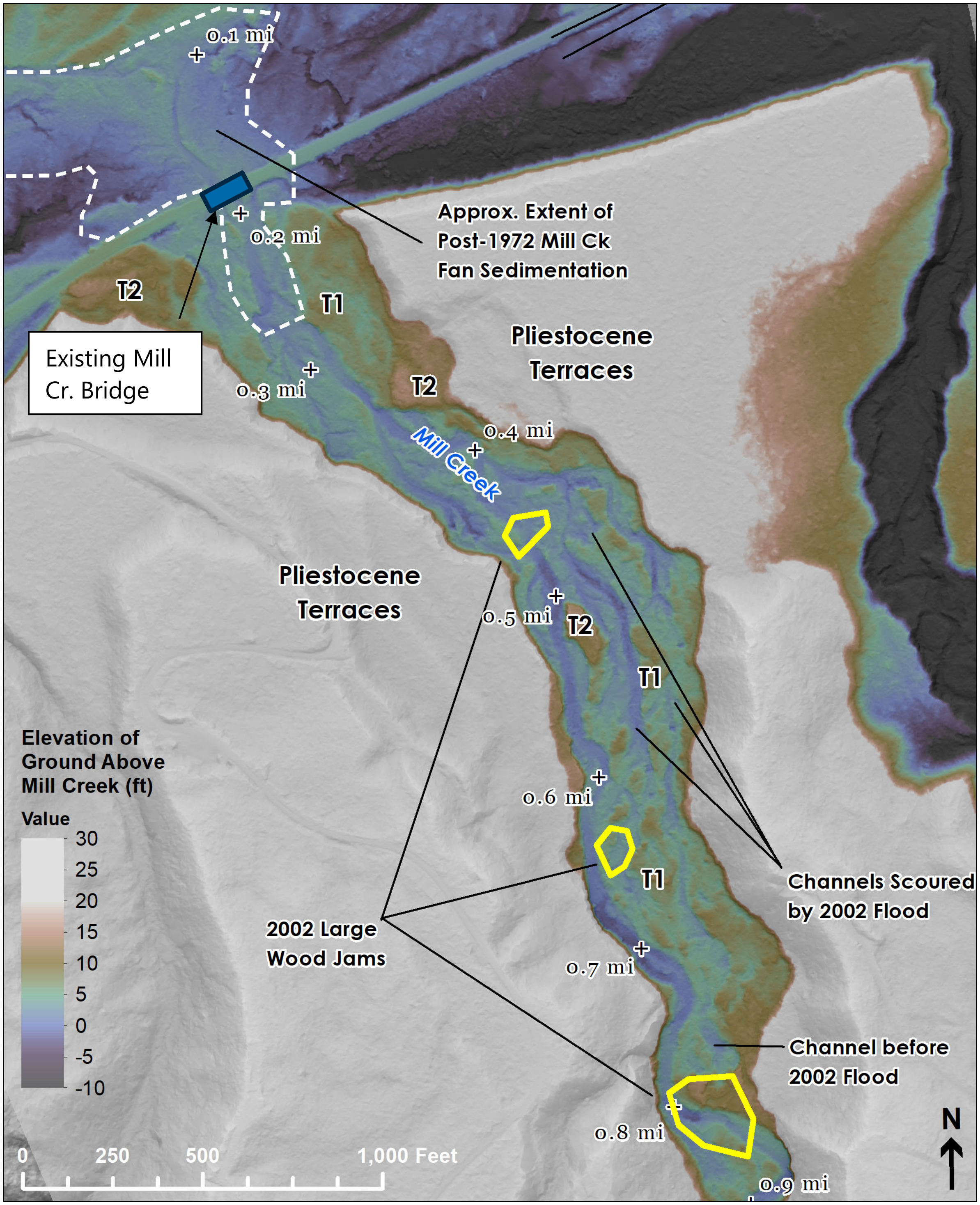

Figure 4: Relative elevation model of mill creek with key features from the 2002 hydrogeomorphic flood, identified by Grizzel (2002), and select other valley bottom geomorphic features annotated.

2 SAVAGE CREEK AND SKAGIT RIVER FLOODPLAIN

Savage Creek debouches from an approximately 300 to 400 ft wide valley that is deeply incised below Pleistocene terraces into the Skagit River Floodplain approximately 2,000 ft upstream of the current Savage Creek culvert under the South Skagit Highway. At this point, it has built up an alluvial fan (Figure 1) that extends to the north. The South Skagit Highway cuts through this fan. In some places the fan was lowered to meet the highway grade, while in others fill was placed blocking potential Savage Creek flow paths and impounding several large ponds and wetlands that lie between the Savage Creek Alluvial fan, terrace escarpment, and South Skagit Highway. Presently, Savage Creek turns abruptly to the west at the fan apex and follows a westerly alignment before entering another pond and wetland that are controlled by interactions between the Mill Creek alluvial fan, South Skagit Highway embankment, and Savage Creek culvert (Figure 1). Given this geomorphic and hydraulic setting, removing the South Skagit Highway embankment opens the possibility of Savage Creek occupying a large area of the Skagit River Floodplain where it may flow between various meander scroll swales across the floodplain.

In the valley upstream of the alluvial fan, the mainstem and side channels of Savage Creek generally anabranch across the entire valley bottom (Figure 1). In many areas, the channel is very wide (on the order of 40-60 ft), poorly defined, and surrounded by very low wet floodplain, while in some areas is slightly more channelized and occupies a 25-35 ft wide channel. Where the main channel abuts the valley wall, cutbanks readily erode into the valley wall toe, indicating the creek is actively expanding the valley bottom.

CLOSURE

We trust this report meets your needs. If you have any questions or requests, please feel free to contact the undersigned.

Sincerely,

Northwest Hydraulic Consultants Ltd.

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REFERENCES

Grizzel, J. (2002 April). *The Mill Creek Debris Torrent: Just Where Did All that Sediment Come From*. [online] Available from: NHC project files.

Jakob, M., Clague, J. J., and Church, M. (2015). Rare and dangerous: Recognizing extra-ordinary events in stream channels. *Canadian Water Resources Journal / Revue canadienne des ressources hydriques*, 1–13. doi:10.1080/07011784.2015.1028451.

NHC (2004). *Mill Creek Bridge 40086 South Skagit Highway Sediment Management / Flood Protection Preliminary Report*. Report Prepared by Northwest Hydraulic Consultants for Skagit County Department of Public Works.

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