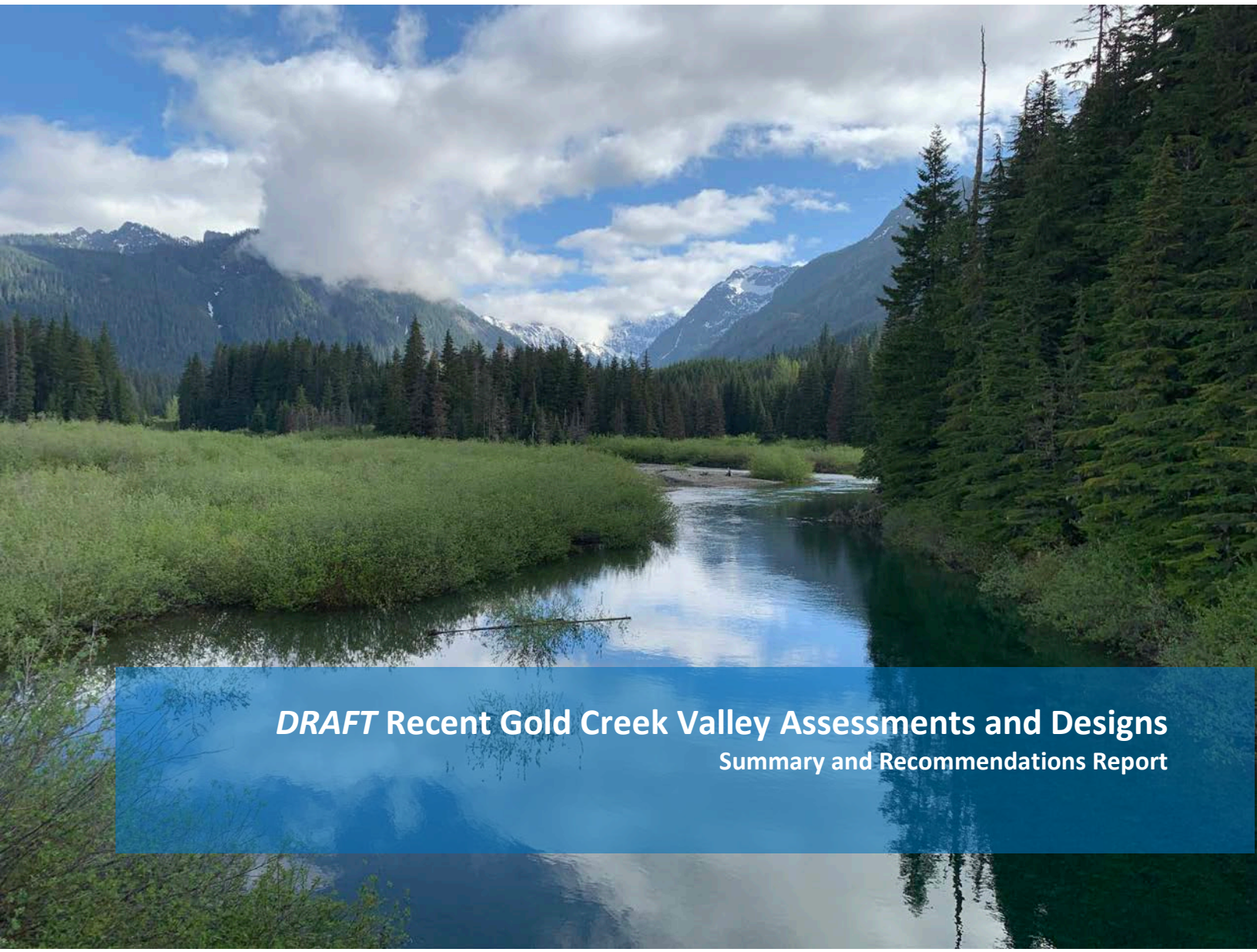


DRAFT Recent Gold Creek Valley Assessments and Designs

Summary and Recommendations Report

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1. BACKGROUND

Gold Creek is the largest tributary draining into Lake Keechelus and is home to an adfluvial population of ESA listed bull trout identified as a tier 1 "action" population in the Yakima Bull Trout Action Plan (Reiss et al 2012, USFWS 2015). The Gold Creek bull trout are genetically distinct from the other two listed native bull trout populations remaining in the Yakima Basin, as the population was isolated following construction of a crib dam in 1905, and the much larger Keechelus Dam in 1917, both built without fish passage. Under the current condition over a mile of the creek dewaters annually, persisting for weeks to months creating a barrier to spawning adults migrating to the headwaters of Gold Creek. As a result, these fish are designated as a high priority action population in the Yakima Bull Trout Action Plan (Reiss et. al. 2012) and have been the focus of years of studies to determine what can be done to restore critically low populations.

In 2012 the Kittitas Conservation Trust initiated what has come to be a number of assessments into the mechanisms contributing to dewatering in Gold Creek, to better understand to movement of water through the valley, and design solutions to address identified limiting factors. The assessments completed have led to the development of engineering designs aimed at limiting the duration and extent of dewatering in Gold Creek. This document is intended to summarize the findings of each assessment conducted and describe the designs completed and put forward a recommendation for actions at Gold Creek based on the designs developed to address limiting factors for Gold Creek bull trout.

1.1 Landscape Setting

Gold Creek lies between the Northern and Central Cascade Mountains, just to the east of the divide separating the Puget Sounds and the Columbia River drainages. Originating high in the Alpine Lakes Wilderness Gold Creek drains a glacially carved valley and empties into Lake Keechelus. Lake Keechelus was a natural lake impounded behind a Pleistocene terminal moraine formed during the Fraser Glaciation period, with the Yakima River originating at the lake's outlet. Gold Creek valley is bounded by Rampart Ridge to the east, Kendall Peak and Alaska Mountain to the west, and Chikamin Ridge to the north forming the valley head. The valley bottom begins to widen south of the Alpine Lakes Wilderness boundary, down to near Gold Creek Pond where the valley begins to constrict again. The valley narrows from Gold Creek Pond to I-90, as an exposure of Eocene extruded volcanics on the western valley margin meets the resistant Naches Formation on the east. The confinement continues down to I-90, below which the valley rapidly expands as it joins Coal Creek valley.

1.2 Geology

The Gold Creek valley is formed by an unnamed normal fault following the axis of the valley, with the eastern side of the valley displaced downward relative to the western side (Tabor et al 2000). The basement rocks are the Naches Formation (Eocene), with varying lithology on either side of the fault. The eastern side of the valley are primarily basalts with clusters of large plagioclase phenocrysts (large crystals), and the western side a mix of volcanic and sandstone assemblages. Intrusion of the granitic Snoqualmie Batholith (Miocene) can be found near Alaska Lake on the western side of the valley and extends across the valley near RM 6.5. Pleistocene (Fraser-age) glacial Evans Creek Drift mantles the Naches Formation along the western valley margin up to near RM 3.5 and Quaternary alluvium forms the valley floor up to RM 6.5. Several Quaternary landslide and talus deposits are mapped within the Gold Creek watershed, indicating mass wasting event have and are likely to continue to occur.

2. ASSESSMENTS COMPLETED

Multiple assessments were conducted to understand dewatering in Gold Creek, as well as habitat conditions within the dewatered reach, to inform the development of actions to limit dewatering and provided needed habitat conditions for Bull trout. At the inception of the project, several assessments were identified as critical to providing a baseline understanding of Gold Creek, including a data inventory and gaps analysis, Bull trout habitat assessment, hydrologic and hydraulic assessments, and a geomorphic assessment. Over time, additional assessments have been conducted to address more targeted questions as a deeper understanding of the systems was needed to develop appropriate actions to limit dewatering in the channel.

2.1 Data Inventory and Gaps

The first steps toward investigating dewatering at Gold Creek was to collect existing reports, studies and data related to Gold Creek to establish the existing knowledge base (NSD 2013a). This information was collected from a range of sources including state, federal, private, and non-profit agencies, local stakeholders, libraries, and online resources. These resources were compiled, reviewed and used to establish the current state of understanding of the mechanisms contributing to dewatering in Gold Creek. A total of 150 references and data sources were identified related to Gold Creek and the surrounding area, including historical documents and air photos, scientific studies, land use history, descriptions of climate, geology and channel morphology.

After reviewing and summarizing the background documents, gaps in data were identified that would be critical to understanding the nature of dewatering in Gold Creek and that should be collected as part of the project. These missing components include:

- Temporal and spatial variability of surface and groundwater elevations prior to, during, and following dewatering in Gold Creek.
- Channel substrate size and distribution
- Spatial distribution of erosional and/or depositional areas
- Spatial distribution of large wood and associated geomorphic features
- Hydraulic conditions in Gold Creek
- Spatial arrangement of pools and other habitats in Gold Creek

2.2 Bull Trout Habitat Memo

An in-depth understanding of the Gold Creek bull trout life cycle and usage of Gold Creek habitats is needed to contextualize and focus the assessments (NSD 2013b). The bull trout that currently utilize Gold Creek are all that remain of a once more abundant population native to the original, smaller pre-dam Lake Keechelus. Although there are only anecdotal accounts and no official numbers, bull trout—at that time believed to be Dolly Varden charr, *Salvelinus malma*—were said to be plentiful in the pre-dam lake (see for example Bickel 1908). Here in the Pacific Northwest, bull trout did not come to be recognized as such until 1978 (Cavender 1978), and only since 1982 have they been acknowledged by the State of Washington as the species actually present in Lake Keechelus (Mongillo and Faulkoner 1982). In 1998, owing to seriously reduced numbers, the U.S. Fish and Wildlife Service listed the entire upper Columbia River distinct population segment of bull trout (including the Lake Keechelus/Gold Creek population) as threatened under the U.S. Endangered Species Act.

Gold Creek bull trout follow what is referred to as an adfluvial (lacustrine or lake-dwelling) life cycle, meaning that they spend most of their lives foraging and growing in the lake environment of Keechelus Reservoir but migrate into Gold Creek for the purpose of reproduction. Adults that survive the rigors of spawning return to the

reservoir—and so do their progeny after spending the first 1 to 3 years of their juvenile lives in the creek. The progeny become sexually mature and ready to spawn themselves for the first time at age 4 or 5 after a year or two of foraging and growth in the reservoir, and can spawn every year thereafter, although many of the adults do not do so in successive years and remain in the reservoir throughout the years that they skip.

Bull trout are fall spawners, but in adfluvial populations the majority of the adults may enter natal tributaries in mid-summer, about two months prior to the initiation of actual spawning (Fraley and Shepard 1989). This is true in Gold Creek as well, where observers have consistently reported the first of the migrants in the stream about the second or third week of July (Craig 1997; Wissmar and Craig 1997; James 2002; Meyer 2002). The majority of the upstream migrants enter between mid-July and mid-August (James 2002) and move quickly upstream to holding pools in the same general segment of the creek where they will later spawn, beginning in early to mid-September. The core segment for holding and spawning extends from roughly RM 3 to RM 5.7. The few migrants that enter the creek later would likely home to this same core segment, were it not for the dewatering of a downstream segment adjacent to the Gold Creek Pond, that in some years may extend as much as 2 miles upstream from the Pond outlet (Reiss et al. 2012). This also occurs around mid-August most years and blocks any further upstream migration.

Redd counts, available for every year since 1984, have served as surrogate estimators of spawning population strength for Gold Creek bull trout. Early studies of Gold Creek bull trout suggest that they exhibited strong fidelity to specific spawning sites. By far the highest densities of redds were observed at just two sites, one a 1st-order spring-fed side channel near RM 4.2 and the other a short upwelling reach in the immediate vicinity of the Silver Creek confluence at RM 4.9. Bull trout blocked by dewatering from migrating upstream will indeed spawn in the stream segment downstream from the Gold Creek Pond outlet, and even in the dewatered reach of Gold Creek once water is flowing in the channel again. But all of this spawning activity takes place in October, late in the spawning season, and not until water temperatures in these segments drop to 46°F (8°C) or lower, which they do not normally do until around the 19th or 20th of October (Goetz 1994; Craig 1997; Thomas 2001; Meyer 2002). The Gold Creek Pond outlet was built to be a spawning channel, but bull trout have seldom (if ever) used it as such. It is, however, used each year by the introduced kokanee that inhabit Lake Keechelus, which typically enter the creek in September and October.

Goetz (1994), James (2002), and Meyer (2002) have each reported on the movements and habitat use of young-of-the-year and older juvenile bull trout in Gold Creek. In the spring and summer months, these fish disperse throughout the stream, with the exception of the outlet from the Gold Creek Pond and the Gold Creek mainstem downstream from the Pond outlet. These two reaches may be avoided because of their elevated summer water temperatures, which are often at or above the 59 to 60°F (15°C) preference level of the species (Thomas 2001; Meyer 2002). Juvenile bull trout have been observed in the Gold Creek Pond itself, however, but always at the northern end of the pond where cold springs discharge. They also use the mainstem reach that dewaters (when water is present in the channel, of course), and often have been found stranded in residual pools when dewatering occurs, especially the age-1 fingerling-sized juveniles. They could survive in those pools provided they have sufficient depth and substrate for concealment and are continually refreshed with a flow of cold subsurface water and hyporheic invertebrate organisms for food, but probably not otherwise.

Age-1 and older juvenile bull trout are, like the adults, bottom dwellers and substrate-oriented. They utilize pools and deeper glides that provide concealment cover such as crevasses, interstitial spaces, large woody debris, undercut banks, and even the “bubble cover” generated by water falling into plunge pools or where riffles and cascades discharge into pools or glides. Goetz (1994), James (2002), and Meyer (2002) have each reported on the movements and habitat use of young-of-the-year and older juvenile bull trout in Gold Creek. In the spring and summer months, these fish disperse throughout the stream, with the exception of the outlet from the Gold Creek Pond and the Gold Creek mainstem downstream from the Pond outlet. These two reaches may be avoided

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Juvenile bull trout tend to remain within concealment cover in their preferred pools and glides during the daytime but are much more active and wide ranging at night. The outmigration of juveniles from Gold Creek is likely to take place either in the spring and early summer or in the very late fall, owing to 1) the dewatering of the segment adjacent to Gold Creek Pond in the late summer-early fall months, and 2) the elevated water temperatures that prevail downstream from the Pond outlet during late summer-early fall (Thomas 2001; Meyer 2002).

2.3 2013 Hydrologic & Hydraulic Assessments Memo

To better understand the spatial and temporal character of groundwater and surface water gradients in Gold Creek valley, a monitoring network was established in 2013 to collect data prior to, during, and after dewatering of the channel (NSD 2013c). Additional field observations of the extent of watered channel over the course of the summer of 2013 were recorded as well to provide more detailed spatial information. A total of 6 groundwater wells and 10 surface water stations were installed along the main channel, eastern floodplain, and in Gold Creek and Heli's Ponds.

Dewatering of Gold Creek initiated on July 24th near RM 1.5 adjacent to the Ski Tur community, propagating up and downstream from that point over the duration of the summer. Brief re-wetting events in response to local thunderstorms were recorded that provide a brief window for migrating bull trout to pass through the project reach on the way to preferred spawning reaches upstream. The channel remained flowing from October 4th on through the end of the calendar year, marking the end of the 2013 dewatering season at Gold Creek. Once dewatering initiated near RM 1.5 it progressed upstream on average 100-ft/day (maximum 170-ft/day) beyond RM 2. The channel dewatered in the downstream direction at 50-ft/day to below RM 1, and largely remained wetted from that point downstream to Lake Keechelus for the duration of the summer, short of a small, dewatered section of creek that briefly emerged just above RM 0.5 as groundwater reached seasonal low levels. The dewatered reach of Gold Creek reached its maximum recorded length of 1.26-mi on September 26th.

Maps of piezometric head including the groundwater wells and surface water stations revealed the extent of influence Gold Creek Pond has on groundwater elevations up-valley of the pond, and the subsequent flow in Gold Creek. The influence of Gold Creek Pond was found to be from the orientation of the upstream end of the pond relative to the valley axis, as well as from the outlet channel conveying groundwater out of the pond to maintain a relatively constant head over the year that is lower than what would naturally be there. The orientation of the pond is such that the northeastern corner of the pond projects further up-valley than the northwest corner. Because the level of the pond is the same at both locations a cross-valley gradient (west to east) is created in the groundwater up-valley of the pond, whereas under natural conditions groundwater will flow directly down valley. This lateral gradient is such that Gold Creek is losing flow to the eastern floodplain at a rate that it cannot maintain surface water.

Groundwater levels up-valley of Gold Creek Pond were found to not fluctuate as much during the year as those further up-valley, suggesting that the proximity to Gold Creek Pond, where water levels are held constant, acts to buffer the adjacent groundwater response to external drivers (i.e., less inflow during the summer months).

The primary conclusions from this assessment are that the groundwater gradients are manipulated by Gold Creek Pond year-round in a way that contributes to the frequency, duration and magnitude of dewatering in Gold Creek. The orientation of the northern edge of the pond relative to the axis of the valley establishes a cross-valley groundwater gradient that moves water from the west side of the valley to the east, effectively draining Gold Creek up-valley of the pond. In addition to the lateral gradient, the absolute elevation of groundwater is suppressed by the outlet channel of Gold Creek Pond maintaining a constant level. If groundwater levels adjacent were to naturally fall to or below the level of Gold Creek Pond, the outlet channel would cease to flow, and the level of the pond would drop with the surrounding groundwater. This condition is present at Heli's Pond, where the pond level drops during the summer months and partially dries up.

In addition to this hydrologic assessment, a 1-dimensional (1-D) hydraulic model (HECRAS) was developed for Gold Creek to characterize hydraulic conditions in the creek at pre-determined recurrence intervals (RI). Discharges were estimated for each RI using maximum average annual daily inflow records to Keechelus Lake (Salminen 1997, USGS 1982). The hydraulic model utilized a LiDAR derived digital terrain model (DTM) acquired in 2012 to represent the channel and floodplains. Seventy-four cross sections were used to develop the model of the reach. For this part of the project, the hydraulic model was used to evaluate the potential influence of Lake Keechelus levels on channel hydraulics in Gold Creek. The findings were that it did not appear the Lake Keechelus levels were influencing dewatering near RM 0.5 in Gold Creek; however, the findings were inconclusive the time and it was concluded that the matter be investigated in more detail.

2.4 2014 Hydrologic Assessment Memo

To better understand the variability of groundwater and surface water conditions year-to-year in Gold Creek valley, a monitoring network was established in 2014 (NSD 2014a) using the same methodology as the 2013 study (NSD 2013c). Additional field observations of the extent of watered channel over the course of the summer of 2014 were recorded as well to provide more detailed spatial information, similar to 2013. A total of 6 groundwater wells and 10 surface water stations were installed along the main channel, eastern floodplain, and in Gold Creek and Heli's Ponds.

Dewatering initiated on August 3rd, 10 days later than the 2013 season but at the same location in the channel adjacent to near RM 1.5 at Ski Tur. Short of several brief summer thunderstorms capable of temporarily re-wetting the channel, dewatering persisted until October 17th when the channel continuously flowed for the remainder of the year.

Similar trends as in 2013 were seen in the results of the 2014 data, with dewatering initiation at the same location in the channel and progressing in a similar manner up and downstream. Groundwater elevations and gradients were also similar to that in 2013. The primary differences were the maximum length of dewatered channel was less in 2014, extending upstream 2665-ft less than in 2013, and the second dewatered reach that emerged in 2013 near RM 0.5 did not form in 2014. Both of these differences are attributed to above average rainfall from July through October providing more water to the system overall relative to 2013.

2.5 Geomorphic Assessment Memo

The geomorphic assessment documents the influence of artificial constraints to natural processes in Gold Creek, and how those influences limit and/or enhance habitat for bull trout (NSD 2014b). A description of the historic conditions prior to significant disturbance is provided, with a timeline of anthropogenic disturbances that have resulted in degraded instream habitat for Gold Creek bull trout.

Prior to large-scale disturbances in Gold Creek, the channel had an anastomosing channel planform with large trees lining the channel banks. As the creek eroded the channel banks during high flow events, the large trees

would be recruited into the channel, forming obstructions that would deflect flow away from the eroding bank while providing instream habitat. This process maintained narrow channels that would have been deeper on average than the current condition, and more connected to the adjacent floodplain as overbank flooding would have been more common.

Early European settlement in the mid-late 1800's (USFS 2011) around the Gold Creek area included mining, logging, and road and railway development. Growth continued in the early 1900's as the US Bureau of Reclamation established the Yakima Project, consisting of a series of dams, reservoirs, and canals to provide water primarily for irrigating fields in the middle and lower Yakima valley. The Keechelus Dam was constructed between 1913 and 1917, raising the level of the lake 92-ft and submerging the lower 1.25-miles (mi) of Gold Creek during the winter and spring as water is stored for summer release. Disturbance in Gold Creek valley above the high-pool level of the lake was small scale with limited impact through the mid-1940's as evident in historic air photos. Large scale logging of the valley occurred by the late 1950's, clearing the forest up to the channel banks and using the main and side channels as skid roads. Estimates from Plum Creek Timber Company suggest that the width of Gold Creek's active channel has nearly tripled since 1941, and that channel bars have grown in size in response to timber harvest (Collins 1997, Meyer 2002). The impact of historic logging on the form of Gold Creek was dramatic and compounded by the removal of the large trees lining the banks that historically checked bank erosion. Without these trees, the banks freely migrated into the floodplain, widening the active channel leaving large expanses of barren gravel bars and a wandering low-flow channel with limited habitat. During the 30 years following logging there was an 90% increase in the average channel width relative to the undisturbed channel. Over time the rate of channel widening diminished, and subsequently the sediment load contributed from bank erosion also decreased. This change in sediment load focused the channel's energy on evacuating the sediment stored in the channel, lowering the overall bed elevation and disconnecting the adjacent floodplain.

In addition to logging of Gold Creek valley, a 27-acre gravel pit was excavated adjacent to Gold Creek that occupies almost 80% of the valley width. The pit was well developed by 1970 and continued operations into the 1980's. The pond was excavated incrementally in a number of "cells" of varying depth comprising the pond, with the deepest cell in the southwestern corner of the pond near 50-ft deep. Large spoil piles remain on-site around the southeastern and western perimeters of the pond. The site was later converted into the Gold Creek Pond day-use area including a parking area, restrooms, picnic area and trail around the pond. The outlet channel flowing along the southern side of the pond acts to maintain the pond at a constant level and remains flowing year-round. The pond is fed by cold groundwater that is visibly seeping in along the northern edge of the pond and minor surface flow contribution from a drain outfall described later.

An 8-in buried drain was identified during the channel surveys that runs along Snowshoe Lane and Gold Creek Road. Several manholes along the roads revealed a network of buried PVC pipe traversing the property northeast of Snowshoe Lane. The drain terminates at a manhole with the bottom broken out, with flow channelizing and flowing into Gold Creek Pond as surface water. It is believed that this drain was constructed sometime in the 1980's and installed to drain groundwater through the proposed Starwater community that was never built. During the spring and fall months flowing water can be heard along the drain, during the summer months flowing water can be heard at the down-valley end of the drain. Based on these observations it was posited that the drain is contributing to dewatering in Gold Creek by accelerating groundwater flow down-valley and into Gold Creek Pond, away from Gold Creek.

An inventory of habitat conditions in Gold Creek found Bull trout habitat in Gold Creek was intricately linked to locations of recruited large trees, with the distribution of pools and cover correlating to the frequency of functional large wood in the channel. Average pool depths are the greatest when formed by hydraulics associated with logjams, and higher wood loading was associated with higher pool frequency, bed texture variability, cover and an overall lower median grain size (D_{50}). These findings suggest that by re-creating the function of the large

trees once recruited into the channel, the pre-disturbance channel planform and shape could be restored that would provide needed instream habitat for Gold Creek bull trout.

2.6 Lower Gold Creek Assessment Memo

This assessment was conducted to provide a more detailed understanding of how the annual fluctuations in Lake Keechelus, and NF-4832, influence geomorphic process and habitat conditions in Gold Creek (NSD 2020a). Management of Lake Keechelus under the Bureau of Reclamation operates the reservoir based on meeting the demands outlined in the Interim Comprehensive Basin Operating Plan (BoR 2002). Flood control operations began in response to the 1948 floods along the Yakima, limiting storage of irrigation water until later in the season. In a typical year, water is stored in the winter and spring months and released during the summer, opposite the natural flow regime and referred to as "flip-flop". Water releases for irrigation begin in June and continue through late August. The dramatic rise and fall cause the shoreline of the lake in the Gold Creek valley to move up to 2-mi as the reservoir is drained, changing the location of the mouth of Gold Creek throughout the year. This water level fluctuation affects sediment transport in Gold Creek, which can have geomorphic consequences to the quality, availability, and function of habitat for Gold Creek bull trout throughout the year.

Historic air photos and maps were used to characterize the response of Gold Creek over time to the fluctuating shoreline of Lake Keechelus, from Gold Creek Pond to I-90. This review found the formation of a delta in Gold Creek at the Lake Keechelus high-pool elevation, extending upstream and resulting in dramatic widening of the creek. The release of copious amounts of sediment following logging in the valley is evident with the rapid growth of the delta after the 1950's. Over time the sediment load diminished, and the upper extent of the active delta has progressed downstream.

Evaluating the influence of the fluctuating level of Lake Keechelus on Gold Creek included a statistical analysis of the timing and magnitude of flooding events capable of transporting bedload and the associated reservoir level. The majority of larger peak flow events (>10-yr flood) occur in November and December, a time when Lake Keechelus pool elevations are typically low. Reservoir storage available at this time is used to control downstream flooding to the extent possible. The response of the reservoir relative to the magnitude of the flow event is a function of the time of year, pre-storm reservoir level, magnitude and duration of the flood event. The greater the flood magnitude, the more likely flow will be retained in the reservoir for downstream flood control, causing the reservoir to rise.

The majority of sediment transport days in Gold Creek occur during peak flow events in the fall when Lake Keechelus is typically low. As the year progresses, pool elevations on average rise, submerging the lower channel and any potential deposits formed during low-pool conditions. An examination of pool elevations during peak flow events shows there is an envelope within which peak flows can typically occur for any given pool elevation, that is a function of the magnitude of the event. More frequent peak flows (2-yr flood) occur when the pool elevation is anywhere between elevation 2445- and 2521-ft (full-pool). However, as flows exceed the 25-yr flood (2200-cfs), pool elevations are limited to above NF-4832 (elev. 2500-ft). Larger floods are capable of dramatically reducing available storage, regardless of time of year they occur, and any bedload sediment in transport during these events would more than likely be deposited upstream of NF-4832, as the reservoir stage would be at or above the road limiting transport further downstream.

A sediment transport model was developed using the 1D sediment transport functionality of HEC-RAS v5.0.7 to evaluate the potential for sediment to deposit in the channel where Gold Creek enters Lake Keechelus, creating a potential migration barrier during low-flow conditions. Steady-state simulations were performed over a range of pool elevations and flood discharges that predict erosion and deposition of sediment along the channel of Gold Creek. Under the historic condition, sediment deposited at the interface with Lake Keechelus would have formed a delta, prograding out into the lake and extending upstream, as gradient is decreased. Because the lake level

would have been relatively static throughout the year, the delta would have grown over time as the channel migrated across. This is in stark contrast to the current condition, where the reservoir rises and falls up to 92- ft annually. This fluctuation of the reservoir creates at least 3 distinct zones within the reservoir where aggradation could occur, potentially forming a new delta. At the first zone, low-pool near the historic Lake Keechelus shoreline, sediment deposited into the reservoir forms a delta. Sediment stored in this lower delta will be further transported via wind generated waves. The second zone is 10-15-ft below full-pool, where sediment in transport could begin to build a delta over time in the channel. Sediment stored in this upper delta would be susceptible to erosion when the reservoir is below full-pool, continuing downstream eventually to the lower delta. The third zone is the reservoir bed between low- and full-pool, where sediment in transport could begin to build a delta in the channel. Deposits formed in this third zone experience erosion when the pool is lower, but also are protected from channel erosion when the pool is higher, and the deposit is submerged under the reservoir

The sediment transport model simulations show the influence of pool elevation on sediment transport in Gold Creek varies, but the response is largely to decrease the transport capacity of the channel below the pool stage, and for a distance upstream up to 350-ft. During the low-pool simulation, there is a general trend of incision, averaging 0.5-ft along the entire channel through the project reach. The only location where the channel is predicted to aggrade is an approximately 300-ft long deposit up to 0.5-ft thick located immediately upstream of the full-pool stage of the reservoir, and where deltaic topset beds are interpreted to be forming the current, active delta. The deposition here is due to a wider channel that dramatically decreases channel depth, initiating sediment deposition down to the full-pool stage. During full-pool conditions (elev. 2521-ft), Lake Keechelus extends upstream past the NF-4832 bridge and up Gold Creek to near sta. 2800-ft. Above the full-pool level, the channel is predicted to adjust in a similar manner as during low-pool, with only a slight increase in the predicted deposition on top of the current delta (between sta. 2880-3175) relative to the low-pool simulation. More notable change occurs below the full-pool level, where transport capacity rapidly diminishes and the channel is predicted to deposit sediment between sta. 2080-2630, averaging 1-ft thick at the toe of the delta front. Downstream of sta. 2080, there are no predicted channel adjustments, as the pool has completely inundated the channel and adjacent floodplain, and the channel has no transport capacity.

Based on these findings, it appears sediment transport capacity is reduced over the current delta above full-pool as flow decelerates over the delta top, predicting deposition at this location regardless of pool stage. This indicates that the feature (delta) is persistent on the landscape and is influencing processes and flow characteristics year-round. The magnitude of channel adjustments (+/-) are generally on the order of 0.5-ft or less, with most channel sections predicting channel lowering (not those above full-pool stage). The results of the sediment transport modeling highlight how little influence NF-4832 has on sediment transport in Gold Creek. Model simulations performed with and without the road, and over a range of discharges and Lake Keechelus pool levels were used to capture the range of potential scenarios in which sediment is mobilized in Gold Creek. There is strikingly little difference between the results for any given pool elevation, indicating that the stage of Lake Keechelus is a larger driver in sediment transport dynamics than NF-4832.

Channel migration and avulsion potential under the current condition were evaluated using the most recently available LiDAR for the project area (2014) and based on our understanding of geomorphic processes and hydraulics in the project reach. A terrain analysis was conducted to evaluate the elevations of the floodplains and side channels relative to the main stem channel to understand avulsion potential. The REM generated for Lower Gold Creek shows the channel is incised for much of its length through the project reach, with banks and adjacent floodplains more than 5-ft higher than the channel and rarely receiving overbank flows. Based on historic record of channel evolution in lower Gold Creek, and analysis of the current condition, it seems there is a low potential for significant channel changes to occur resulting from expanding the NF-4832 bridge and leaving the channel largely as-is. The road embankment and bridge are shown not to influence the creek until flows begin to reach the 10-yr flood discharge. And for larger, less frequent floods, the elevation of Lake Keechelus pool is typically above

the NF-4832 bridge, drowning out any influence the road would have had on hydraulics and channel migration and/or avulsion potential.

A network of 9 groundwater and 9 surface water monitoring locations were established to evaluate any potential influence of NF-4832 on these wetlands. There are 5 surface water monitoring locations in Gold Creek, and 4 in off-channel wetlands with perennial open water. The hydrologic monitoring that was conducted reveals that the influence of historic disturbances in the floodplain continue to influence groundwater-surface water exchange through the project reach. The 0.5-ac gravel pit excavated below full-pool in the 1950's and 60's continues to influence groundwater gradients locally, and the straightening and subsequent incision of Gold Creek through NF-4832 and I-90. Surface water elevations in Gold Creek are higher than groundwater and off-channel open water locations monitored at and upstream of the abandoned 0.5-ac gravel pit. This reach of the creek is gaining from the western side but losing to the eastern side. Downstream of the gravel pit, surface waters in Gold Creek are at or below the adjacent groundwater and off-channel open water sites, reflecting a switch from a losing to gaining reach of the creek. These conditions are persistent throughout the year; losing reaches remain losing and gaining reaches remain gaining. Downstream of NF-4832, groundwater and surface waters are close to being in equilibrium for much of the year. Overall, groundwater flow direction downstream of the gravel pit is from the northwest to southeast and remains so throughout the year. At the downstream end of the project reach, Gold Creek flows through the NF-4832 bridge on the eastern side of the valley. The channel has remained in this location for over a century, has been straightened, and subsequently incised to its current condition. The lowering of the creek bed would have lowered the surface water in the creek as well, increasing the gradient with the adjacent groundwater and lowering it in response. This effect appears to dampen downstream of the NF-4832 bridge.

2.7 Gold Creek Valley Wetlands & Waters Summary

A wetland reconnaissance in Gold Creek valley was conducted to support design development, the USFS NEPA process and related preliminary discussions regarding federal, state and local permits (NSD 2020b). The reconnaissance documents the approximate extent and general nature of wetlands. It also provides information regarding the hydrogeomorphic (HGM) characteristics, vegetation classes, and general ecological functions of the wetlands within the study area. To ultimately secure construction permits, a formal wetland delineation will need to be conducted and a jurisdictional determination of the presence and extent of wetlands, streams, and other waters of the United States will need to be made by the Seattle District, Regulatory Branch of the U.S. Army Corps of Engineers (Corps). Related federal, state, and local permitting requirements and authorizations will also need to be sought through the Corps, the U.S. Fish and Wildlife Service, U.S. Forest Service (USFS), the Washington State Department of Ecology (Ecology), the Washington Department of Natural Resources (WDNR), the Washington Department of Fish and Wildlife (WDFW), and Kittitas County respectively. NSD investigated the wetland reconnaissance study area to determine the potential presence of wetlands and determine their approximate location and extent. The study area did not include approximately 74 acres of private land, most of which is located north of the pond.

Under Section 404 of the Clean Water Act, a wetland is defined as an area "inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (Federal Register 1986:41251). Under normal circumstances, the 1987 manual and the Regional Supplement (Environmental Laboratory 1987, 2010) require the presence of wetland indicators for hydrophytic vegetation, hydrology, and hydric soils for an area to be considered a wetland.

In addition to information gathered through review of the background data, and considerations of geomorphic position and modeled 2-year flow in Gold Creek, NSD wetland biologists considered indicators of wetland vegetation, soils, and hydrology during the reconnaissance field effort. These indicators were noted in the field

and considered in the conclusions of potential wetland extent with the anticipation that data collected during this effort would support future project specific field delineation in areas of potential direct impacts on wetlands and waters of the U.S.

Wetland data plots were collected in potential wetland areas using the *Regional Supplement* (Environmental Laboratory 2010) field data forms. The teams collected sample plots in each of the representative types of wetlands within the study area, as presented in Attachment B, *U.S. Army Corps of Engineers Wetland Determination MVC Data Forms,* as well as notes, photos, and other data to document field observations.

Based on the field work conducted October 11, 17, and 24, 2019, NSD concluded that approximately 33 potential wetlands totaling 69.7 acres are present within the study area. The study area is generally characterized by the following six types of wetlands: riverine wetlands along edges of Gold Creek, wetlands scattered in the historic floodplain to the north, depressional wetlands within the influence of Lake Keechelus backwater, inner slope and narrow shallows of Gold Creek Pond and Heli's Pond, narrow areas of slope wetlands along the northern and northeastern edges of Gold Creek Pond and wetland weeps impounded at the slope toe along the eastern side of the pond, and wetland/upland mosaic south of USFS parking lot. The general characteristic of each of the six types are represented by representative wetlands that are described in detail of vegetation communities present, soil and hydrology wetland indicators, a preliminary determination if wetland will be determined regulated, and wetland category and functions (water quality, hydrologic, habitat).

The limits of ordinary high water marks (OHWM) defining the limits of Waters of the U.S. was estimated to be at the margins of the active floodplain and contains within it sparsely vegetated gravel bar areas. NSD then considered this field estimated OWHM against the extent of inundation illustrated by NSD's 2D hydraulic modelling of the 2-year flow (approximately 1,100 cfs) and found the extent to align closely with the observed field indicators. The narrow and well-defined outlet channel of Gold Creek Pond flows year-round and directly connects the pond and the creek. As such, it would be considered a water of the U.S. NSD's field estimate of the OHWM of the outlet channel was similarly based the presence of scour lines, flood debris and deposits, clean cobbles and gravels, and the limit of upland vegetation adjacent to the channel.

At the time of the field reconnaissance, NSD determined that the study area supports Waters of the U.S. in the form of Gold Creek, adjacent wetlands that abut Gold Creek or Gold Creek Pond and its outlet channel, and wetlands that have significant nexus to these features via surface and/or groundwater connection. We found that the study area generally does not appear to contain roadside ditches with relatively permanent flow. Water conveyed under Forest Service Road 144 generally flows through culverts beneath the road and then perpendicular to the road. Water is conveyed downslope, forming wetlands that are connected via surface or subsurface hydrology to the creek and pond and ultimately to Lake Keechelus.

A determination of whether all wetlands within the study area meet the new definition of Waters of the U.S. will need to be made by the Seattle District of the Corps of Engineers during the proposed project's regulatory compliance process.

2.8 Gold Creek Valley Groundwater Model

A groundwater model was developed to evaluate the performance of proposed designs in limiting the extent and duration of dewatering in Gold Creek. Models were developed representing conditions during dewatering (summer months) and during the recession of the spring freshet (June) (NSD in press). The groundwater model was developed using MODFLOW, which is the USGS modular finite-difference flow model and is a computer code that solves the groundwater flow equation through aquifers. Aquaveo's Groundwater Modeling Software (GMS) was the graphical user interface used to set up and run the MODFLOW model. MODFLOW utilizes a generalized control-volume finite-difference approach in which cells in the model can influence any number of adjacent cells.

In order to simulate a three-dimensional groundwater flow model, MODFLOW requires several input parameters to set up the model and solve the partial differential equation. All input parameters for the existing and proposed conditions Heli's Pond model are defined below. The model domain extends 4,000-ft upstream of Heli's Pond and 3,0000-ft downstream of Gold Creek Pond. A single layer aquifer model was developed with hydrologic properties defined for each cell in the model using the Layer-Property Flow (LFP) package of MODFLOW. The general head boundary (GHB) package was used to model Gold Creek Pond and Starwater drainage, and the input parameters along each point, arc, or polygon feature is head and hydraulic conductance.

The stream (STR) package was used to model Gold Creek, and the two outlet channels that connect each pond to Gold Creek. The STR package simulates the interaction between surficial streams and groundwater, and the package requires input parameters along stream arcs to solve Manning's equation, including hydraulic conductance, stream width, sinuosity, roughness, and incoming flow. Hydraulic conductivity is defined throughout the model domain by zones that are initially based on independent information such as aquifer testes or literature values appropriate to the dominant type of rock but are then refined during model calibration. Hydraulic conductivity for this model was separated into channel zones and valley zones and was calibrated to the groundwater and surface water observation well head values. The recharge (RCH) package was used to simulate recharge to an aquifer due to rainfall and infiltration, and the input value represents the amount of water that goes into the groundwater system. A constant recharge value of 0.0007 ft/d was used for the entire model domain.

The existing conditions groundwater model was developed and calibrated using observation wells installed throughout the valley. Observed head values in these wells were used to calibrate hydraulic conductivity along streams, ponds, and in the valley aquifer. Proposed conditions models were developed for each design alternative for Gold Creek Pond by incorporating the new terrain representing the proposed design developed in CAD and MODFLOW packages removed and/or added based on the design alternative. Simulations during the spring freshet and the summer were conducted for the existing conditions model and each of the proposed conditions models. The results of each simulations were viewed to display cells within the model that predict groundwater head above the ground surface, or groundwater expressing as surface water. The number of these cells along Gold Creek were counted for each alternative and used as a proxy for re-introducing water to Gold Creek.

All of the proposed design alternatives developed predict more water in Gold Creek during the spring freshet and during the summer months relative to the existing condition. Increases in water during the spring were significantly less (max. 17% increase) than during the summer (max. 228%), signifying modifications to flow would be most pronounced during the summer when dewatering currently occurs. Under the current condition during the summer months there are 5.25-acres (ac) of Gold Creek that are wetted via groundwater emergence above the ground. The creek integration concept alternative, diverting Gold Creek into the northwestern corner of Gold Creek Pond, predicts 12-ac of Gold Creek wetted during the same time, the most increase of all the alternatives modeled. The multi-pond concept alternative, dividing the current pond into a number of smaller ponds of varying water levels, and the multi-pond & creek integration concept alternative, a combination of the multi-pond and creek integration, both predict 9 and 9.75-ac of Gold Creek wetted during the summer, respectively. The alternative combining the forested wetland complex and creek integration predicts 9.6-ac of Gold Creek wetted during the summer months. The forested wetland complex concept alternative, filling the pond to create a mosaic of uplands, wetlands, and open water, predicts 7.5-ac of Gold Creek wetted during the summer. These results suggest that any of the proposed concept alternatives would most likely be successful in keeping the majority of pools along Gold Creek wet through the summer months, one of the most critical times of year for Gold Creek bull trout attempting to migrate upstream to spawn. The model results also suggest that depending on the alternative there is potential for the creek to have sections within the current dewatered channel with flowing water during the summer months.

Simulations were also performed with and without the Starwater drain line that parallels Snowshoe Lane. The drain was modeled using a variety of techniques and packages within MODFLOW, and regardless of approach the drain lowers groundwater elevations up-gradient of the drain creating a sink in the aquifer with more flow leaving than entering. While the Starwater drain was found to effectively lower groundwater elevations, the magnitude was considerably less relative to Gold Creek Pond.

Groundwater modeling of Gold Creek valley demonstrates the influence of Gold Creek Pond in contributing to dewatering of Gold Creek, and that proposed actions at the pond could dramatically re-wet the channel within the reach that currently dewaters annually. The influence of the pond is more significant during the summer months when groundwater conditions are naturally low, and the creek is dewatered than during the spring when groundwater is high.

3. DESIGNS COMPLETED

3.1 Gold Creek Valley Concept Designs

Based on the findings of the data inventory and gaps analysis, bull trout habitat assessment, 2013 and 2014 hydrologic assessments and geomorphic assessment, conceptual level designs were developed to address identified contributors to dewatering and degraded habitat conditions (NSD 2015).

Gold Creek Pond was identified as the likely primary contributor to dewatering of Gold Creek due to the lateral gradient setup by the northern edge of the pond not being perpendicular to the valley axis, and an overall lowering of groundwater levels due to the size of the pond projecting up-gradient with the same water level. Five concept design alternatives were developed to minimize the influence of the pond on the surrounding groundwater. These alternatives include: complete fill of the pond and restore the site to pre-mining conditions, partial filling of the pond (northeastern corner), raising the inlet of the outlet channel to raise the level of the pond, move the outlet channel to the northwestern corner of the pond and raise inlet, and to fill the outlet channel completely and allow the pond level to fluctuate seasonally. Of these alternatives, the concept to fill the pond and restore the site to pre-mining conditions was presented as the recommended alternative based on it having the greatest likelihood of restoring natural flows to Gold Creek. The rationale is that if the site is restored to the wetland complex that was present prior to Gold Creek Pond, it would restore the groundwater and surface water characteristics present prior to the pond. This alternative also has the added benefit of relying on natural process to create, restore and maintain the proposed condition, versus other alternatives would maintain an artificial static landscape that requires periodic maintenance.

Within Gold Creek, habitat conditions are degraded as there are few pools, little to no cover or instream wood, and the low-flow channel is very unstable and wanders across the over-widened active channel frequently. Proposed restoration of Gold Creek focuses on narrowing the active channel width to more closely match that found prior to logging by accelerating the natural process that would narrow the channel over time. The large trees that once lined the banks of Gold Creek would be recruited as the banks eroded. Once in the channel the trees deflect flows away from the eroding banks, limiting further erosion while providing instream cover and likely pool formation. The proposed design would import large trees and arrange them along the current channel banks, simulating the recruitment process, and then backfill the placed trees to create a low floodplain bench resulting in a narrower channel. Additional wood would protrude from the floodplain bench, providing habitat should the channel impinge on the new floodplain, and native riparian trees would be planted on the surface. In addition to these floodplain benches, vegetated islands could be created using a similar approach to bifurcate the channel, creating a more anastomosing planform as was present prior to recent disturbances. Engineered logjams (ELJs) are proposed along the length of the channel to provide instream cover, force pool formation, partition shear stresses in the channel to limit erosion, and help to maintain channel splits over time.

Heli's Pond as identified as potentially contributing to dewatering in Gold Creek, however a more detailed study was recommended to better understand the exchange of groundwater and surface water at Heli's Pond. While monitoring in Heli's Pond and Gold Creek showed the pond higher than the adjacent creek, there was no monitoring above the pond to determine if it is drawing water from above the pond, similar to how Gold Creek Pond contributes to dewatering of Gold Creek. The furthest upstream extent of observed dewatering in Gold Creek also extends to just above Heli's Pond, where this influence would be focused if present. Should Heli's Pond be found to be contributing to dewatering in Gold Creek a restoration design was developed that coverts the pond into a seasonal wetland to provide some additional habitat benefits.

The buried drain (Starwater drain) identified paralleling Snowshoe Lane and Gold Creek Road appears to have been installed to drain a plot of land that has not been developed. As mentioned previously, water can be heard flowing in the drain throughout the year, indicating it is actively draining even during the summer months when the creek is dewatered. Inspection of the drain shows it is in disrepair with cracked and uncovered manholes. Due to the drain functioning as the creek is dewatered, and the parcel of land was never developed further, it was recommended that the drain be sealed.

3.2 Gold Creek Instream Preliminary Designs (60%)

The conceptual restoration design developed for Gold Creek were further developed to the 60% preliminary design level (NSD 2017a). Refinement and further development of the concept design included identifying the locations and elevations of proposed restoration elements that will maximize the habitat benefits and diminish dewatering in the creek, while not increasing risk to landowners in the valley.

The restoration approach for the project reach is to mimic the natural recovery processes of the creek to restore the historic width of the channel, improve floodplain and side channel connectivity, potentially limit the duration of annual dewatering of the creek, and increase instream and side channel habitat complexity. Given sufficient time and with no logging, trees of sufficient size to remain stable in the creek once recruited will populate the banks of Gold Creek. Once recruited into the creek, these trees will deflect flow away from the channel banks, forming a zone of deposition in the lee that will accumulate sediment and vegetate, creating new floodplain within the current creek banks. The cumulative recruitment of trees this size along the project reach would, over time, reduce the channel width back to its pre-disturbance historic width of 96-ft on average. To accelerate this process, the proposed design includes stable logjams (engineered logjams - ELJs) that project out into the channel, mimicking large stable trees. Additional logjams in the center of the current channel are included in the design as well to force the channel to split into multiple flow paths, restoring the historic anabranch planform and forming islands in the lee (NSD, 2014b).

Flow obstruction due to the logjams will result in an increase in the flow depths over the range of flow conditions, resulting in improved floodplain and side channel connectivity. This increase in off-channel habitat availability will provide refugia for rearing fish during high flows in the creek, as well as recharge groundwater in the adjacent floodplain. Development within the floodplain requires that the design not increase flood and erosion risk to existing homes and infrastructure, therefore the design must accommodate improving floodplain and side channel connectivity but only where it does not increase risk to private property. Strategic excavations are proposed along existing side channels that are currently disconnected from the main channel that will route water into the adjacent floodplain where there is no development.

There are 4 distinct types of ELJs proposed for the project, each providing habitat benefits while accelerating recovery of the channel planform. Large (Type-1; 60-ft wide) and medium (Type 2; 40-ft wide) ELJs can be placed mid-channel to form an island in the channel or along the banks to deflect flows away, splitting flows and narrowing the channel. Type-3 ELJs are smaller bank structures that project less into the flow than Type-1 and 2 ELJs, eliciting a more local response and habitat benefit relative to the larger ELJs. The Type-4 ELJ is a channel

spanning flow deflector intended to plug existing flow paths that convey floodplain waters back to the main stem channel.

Side and anabranch channel excavation locations were identified during the concept design, with 5 channels currently proposed for the preliminary design to provide improved floodplain connectivity and restoration of the historic channel planform (anabranch channel, NSD 2014b). Additionally, these side channel excavations route floodwaters onto the western floodplain to limit additional flooding to existing development on the eastern floodplain. The addition of ELJs to the channel will obstruct flows, causing them to raise floodwaters relative to the current condition. This rise is offset by diverting flow onto the western floodplain through a series of side channels around the existing development. Once downstream of the development floodwaters on the western floodplain are capable of returning to the main stem channel. The locations of the proposed channel excavations typically followed existing features on the landscape such as perched side channels that are currently disconnected from flow, and historic channel alignments of the creek. A total of 23,570-cy of excavation is proposed for all of the side channel alignments combined.

Planting of the riparian zone within the Project reach is proposed that will accelerate recovery of the riparian corridor. Constructed restoration elements proposed for the Project will be planted with native species appropriate for the anticipated hydrologic regime within the creek (low and wet vs. high and dry). Re- vegetation of the project site following construction will be a critical component needed to meet the project goals.

Several access routes were identified that could be utilized to construct the proposed restoration elements. Access for construction could utilize the existing road network within the valley to get as close to entry points to the creek as possible. Entry to the creek is proposed where the existing forest has been recently cleared, minimizing further clearing and disturbance. The existing road network utilized during construction will be restored back to or in better condition than that prior to construction. Restoration of the road will occur following demobilization. Primary staging for the project is anticipated to be outside of but close to the project area. Initial delivery of materials for inspection, sorting and staging will occur at the primary staging site, then transported to the project site once the materials are needed. Multiple small temporary staging areas along the project reach are proposed where materials for nearby proposed structures will be delivered. The timing of material delivery will be such that 1) it minimizes the time logs are sitting in the project reach prior to installation, and 2) all permit requirements are met. Instream flow conditions, largely driven by the proceeding winter snowpack, will likely dictate the timing of material delivery and instream work window. The location, size, and extents of temporary staging areas will be refined to minimize impacts to existing vegetation within the creek. All staging areas will be restored to or better than their pre-existing condition.

An assessment of the changes to hydraulic conditions in Gold Creek resulting from the proposed project was conducted by manipulating the existing conditions hydraulic model developed earlier. Proposed elements were incorporated into the model and flows re-run to simulate the changes to flow depths and velocities. These results were compared to the existing conditions to evaluate the changes. Under the proposed condition, flows during the 2-yr flood more than half of the flow will be diverted onto the western floodplain; however, depths in the main stem channel are predicted to be within 0.5-ft or less of the current depth. Flow velocities are on average 3-ft/s less under the proposed condition due to shear stress partitioning from ELJs, significantly reducing bank erosion potential. During larger floods the pattern of change is similar, however with a larger percentage of the total flow diverted onto the western floodplain as flow increases. These results demonstrate how the proposed project will meet the objectives of narrowing the channel width (diminished bank erosion from lower velocity), improve floodplain connectivity (deflection of flow onto western floodplain), increase instream and side channel habitat complexity (more wood and more flow more frequently), and potentially limit the duration of dewatering (decreased width to limit infiltration potential and storing spring freshet flows in western floodplain for release during the summer).

The proposed ELJs will also provide approximately 73 additional deep pools (estimated by number of proposed ELJs) along 1.1-mi of Gold Creek, providing habitat complexity and cover. These scour pools will also be the deepest points along the thalweg, with the hope that they can maintain water (via lateral connectivity to groundwater) further into the summer months, even after much of the creek is dry. The current channel has an average of 53-pools/RM, representing approximately 59 pools within the project reach (1.1-RM long) (NSD 2014b). Including the additional pools anticipated resulting from the proposed project (73) increases the total number of pools to 132, increasing the average pool spacing to 120-pools/RM. This more than doubling of pool frequency will reduce the average distance between pools from 100-ft to 44-ft, dramatically increasing the likelihood fish will find refuge during annual dewatering.

ELJs and new floodplain areas reduce the active channel width by constricting the channel, while creating hydraulic complexity (fast, slow, deep, and shallow water all in close proximity) in the mainstem channel that will provide habitat complexity. Specific ELJs are arranged at the inlets to new side channels to enhance flow deflection into the new channels, introducing all but low-flows into the western floodplain. The arrangement of structures adjacent to the inlets was iteratively modified to meet requirements needed during both low and high flow conditions.

These results highlight the potential for the additional flow diverted onto the western floodplain in limiting the duration and/or spatial extents of annual dewatering in the creek. However, the contribution to supplementing groundwater on the western floodplain as a result of this deflected flow will be a function of future snowpack conditions (contributing to the volume of potential freshet flow), and the timing and speed of snowmelt in the spring.

The combination of proposed instream ELJs, new floodplain areas and side channels will all contribute to meeting the project goals by accelerating natural recovery processes. Further refinement of the proposed design is anticipated as development continues to final design. Additional project details related to implementation, permitting, access and staging, and bid documents will also be included in the final design.

3.2.1 Gold Creek Risk Assessment

Due to the proximity of existing development a risk assessment was conducted to evaluate the risks associated with the proposed instream restoration project, including natural and non-natural hazards (NSD 2017b). Primary natural hazards for the project area included in this assessment are from flooding and erosion from Gold Creek, including lateral bank erosion, inundation, sediment deposition, the influence of natural large woody material (LWM), and channel avulsion. Natural variability in weather will impact magnitude of each hazard assessed, thus the anticipated effects of climate change will impact future risk. Non-natural hazards included in this assessment are the failure of instream structures, increases in water surface elevation (WSE) or instream velocities as a result of the project, and temporary construction activities.

Risk is a function of the probability of a hazard occurring (such as structure failure/washout, flood inundation, etc.) and the consequences of that event (e.g., habitat loss, property damage, or injury). If an event has little or no consequence, then the associated risk would be relatively low. For instance, if a piece of LWM is mobilized during a flood but there are no adverse consequences, then risk is negligible. However, if the LWM is a critical habitat element or poses risk to property if mobilized, then risk would be considered high. Generally, a high negative consequence coupled with a high probability of occurrence results in a high-risk factor. Alternatively, a low negative consequence combined with a low probability of occurrence results in a low risk factor. A medium risk factor results when one component is high while the other is low.

This risk assessment establishes due diligence in evaluating the preliminary design and consists of the following elements:

- Assessment of short-term risk associated with construction activities
- Assessment of potential impacts to property and habitat
- Assessment of structure stability for restoration elements
- An assessment of potential impacts of restoration elements on existing processes

Hazards associated with construction activities that pose potential risk to water and habitat quality assessed included those from earthmoving, planting, water management and ELJ construction. The risks associated with earthmoving from flooding and erosion is very low given construction will likely occur during summer low (to no) flows. The primary risk to establishment of plantings is from drying during the summer months, and from flooding and erosion primarily in the fall. Selection of appropriate native vegetation and installation to sufficient depths will be used to mitigate risk to the success of planting efforts. Isolation and de-watering of the channel may be needed to install proposed ELJs as the structures are partially buried below the channel bed. Best management practices (BMPs) will be employed to minimize the risk by isolating the work area and removing fish prior to dewatering (pumping excavated pit where ELJ is to be installed). Pumping water will be treated by allowing it to naturally infiltrate back into the groundwater by discharging onto the adjacent western floodplain or in an excavated sump. Construction of design elements will be performed when the channel is slowly drying up in the early summer months and continue through the dewatered period throughout the end of summer. The primary risk to project elements during construction is from flooding and erosion of the work area from short-duration, high-intensity thunderstorms that can re-wet the channel. The risk to locations under active construction could be minimized by installing additional BMPs proceeding or during the event. The low likelihood of a flood with sufficient magnitude to result in damage results in a low risk for constructing instream structures. All work involving excavation in the active channel will include a water management plan.

Potential impacts to property and habitat resulting from the proposed restoration project were assessed using results from the existing and proposed hydraulic modeling. Primary concerns within the project reach include the potential harm to bull trout during construction, and damage (flooding and erosion) to private property and development on the eastern floodplain as a result of the project. Each of these concerns as well as the risk to existing habitat were assessed.

There are several private properties along the left bank of the channel on the east side of valley. These properties vary in the types of landowner, existing development, and risk profile under the current condition. Most of the landowners are private individuals or groups (Ski Tur), with the remaining land held by the USFS and Forterra. Development on the floodplain includes the construction of roads, buried utilities, cabins, flood control measures, gravel pits, and unimproved trails. Within the creek, rock barbs have been installed and repaired several times, and logs of varying sizes and arrangements have been cabled together all in an effort to reduce bank erosion at key locations on the left bank. Erosion of property has occurred over the years on both banks of the channel and has only been halted by installing rock barbs where homes are at immediate risk from further erosion. The results of the hydraulic modeling show locations where the banks are current eroding or where barbs have been installed, channel velocities under the proposed condition are half that under current conditions. The overall reduction in main stem channel velocity will reduce bank erosion rates over the long term along the entire project reach, demonstrating that the proposed design will not increase and likely decrease risk associated with bank erosion in the project reach. The proposed conditions hydraulic model results were also used to assess the relative risk to property and development from flooding. Between RM 1.35 – 1.75 there are 5 cabins, and 200-ft of road/driveway, impacted by flooding currently during the 100-yr (3,000-cfs) flood. Inundation depths adjacent to the cabins ranges from 0.1 – 2-ft, with those most impacted located at the downstream end. The potential damage associated with this level of flooding is to ground-level portions of the cabins in contact with the flood waters. Under the proposed condition flood depths during the same flow are

the same as under the current condition, owing to the deflection of flood waters onto the western floodplain. Habitat conditions within Gold Creek are degraded relative to the historic condition due to disturbances that began in the 1940's, resulting in an over-widened channel lacking large wood with cover and pools. The over-widening of the channel has also increased the capacity of the channel to convey flood flows, reducing the amount of water engaged with the floodplain. Disconnection with the floodplain results in a loss of important side channel and floodplain habitats, as well as focuses all of the stream energy on the main stem channel. The proposed project will add more than 70 pools to the creek, more than doubling pools/RM and dramatically increasing the likelihood fish will find refuge during annual dewatering to hold in and providing cover for rearing juveniles. This will dramatically improve instream habitat over the range of life stages of bull trout and will mitigate for any loss of existing habitat that may be currently available.

The risk associated with long-term aggradation in Gold Creek as a result of the project is the same or less than the current risk. Sediment transport capacity from the main stem channel is reduced and is increased in the proposed western floodplain side channels, as a result of the project. The proposed design will reduce to risks associated with LWM moving through the project, by strategically locating structures and designing them to shed wood during large floods. Risk is diminished relative to the current risk by improving the predictability of locations where wood will accumulate and locating structures upstream of where there is current risk to collect incoming LWM. The primary drivers contributing to the potential for a channel avulsion were evaluated for the new channels included in the proposed design, and existing side channels potentially impacting existing development, and were determined to be low based on the assessment completed. The near equal hydraulic gradient at the channel inlets, and smooth gradients along the channels and at the downstream confluence, demonstrate a low risk of avulsion initiation.

3.3 Gold Creek Pond Concept Designs

The Yakima Basin Integrated Plan funded the development of 2 additional concept design alternatives for Gold Creek Pond (NSD 2019). The additional alternatives were developed largely with feedback from a design charrette held with federal, state, and local agencies involved with the project over the years, as well as local landowners (KCT 2018). These 2 additional concept design alternatives, as well as the original forested wetland complex alternative, are presented with accompanying figures illustrating the proposed design alternatives.

The previously developed forested wetland complex concept design proposes to fill most of the pond and restore the area back to the pre-mining condition, including uplands, wetlands, and open water. Additionally, spoil piles around the pond, outlet channel, and other infrastructure (parking area, roads, restrooms, trails, etc.) would be removed. Tributary drainages would be re-established through the site and reconnected to Gold Creek. By restoring the site back to its historic landscape, the influence of the pond to adjacent groundwater and surface water can be significantly reduced if not eliminated completely. The anticipated response in the creek is to prolong the onset of dewatering later into the summer and reduce the duration of dewatering during the summer months.

The first new alternative approach developed to restoring groundwater conditions upstream of and through Gold Creek Pond is to partition the pond into a series of smaller ponds with varying water levels, descending in elevation down-valley to mimic the natural groundwater profile. While not determined, a significant portion of the pond would need to be filled to implement this alternative, as the partitions would require a wide base to be stable. The intent of this approach is to have groundwater enter the northern-most pond and spill into the next pond with a lower water level. Water would subsequently spill to another lower pond, an onward until it is discharged back into Gold Creek via a new outlet channel.

The other approach to limiting dewatering of Gold Creek is to divert Gold Creek into a partially filled pond, allowing transported sediment from upstream to fill the remaining parts of the pond over time. This approach would create in-line habitat improving access for the restored area for fish, allowing migrating fish to hold in the ponds or

adjacent wetlands if needed. Once the creek has filled the remaining ponds the creek would form a large meander across the valley through the restored site opening the entire floodplain to natural processes and function.

Recreation amenities will be developed for the area once a preferred design alternative has been selected to fit within the new landscape. The USFS has communicated that regardless of the proposed restoration concept selected, recreation opportunities will be included that provide similar opportunities for the public to experience the landscape. The proposed amenities should consider locations and materials that facilitate natural process to form and maintain habitat over the long term.

3.4 Heli's Pond Preliminary Designs (30%)

Based on the initial recommendations put forth in the Gold Creek Valley Concept Design Memo (NSD 2019), the groundwater model developed to evaluate Gold Creek Pond was used to assess if Heli's Pond is contributing to dewatering in Gold Creek (NSD 2020c). And if the results showed the pond is contributing to dewatering, to develop a design to mitigate the influence.

The existing conditions groundwater model was modified to fill-in Heli's Pond, mimicking conditions if it were not there, to assess if the pond is contributing to dewatering in Gold Creek. The results show that Heli's Pond is contributing to dewatering, in a similar manner as Gold Creek Pond, by draining the floodplain and channel up-gradient of the pond. The number of cells in the model predicting groundwater elevations above the ground (surface expression of groundwater) along Gold Creek were again used as a proxy for the influence of the pond and proposed alternatives. Two additional alternatives to a full-fill of Heli's Pond were considered, filling the pond to 50% and 75% of the total depth. These alternatives were developed to determine if filling less of the pond could realize similar results to a full-fill. Simulations were performed to simulate summer conditions and spring conditions using the same methods outlined in the Gold Creek Valley Groundwater Model report.

It was found that between 75 – 100% of Heli's Pond depth should be filled. Filling to 75% of the depth would require an estimated 6,600 cubic yards (cy) of fill, while 100% of the depth would require 17,600-cy of fill. To maximize the balance between costs and anticipated response in Gold Creek, Forterra concluded pursuing the 75% fill option would be best at this stage of design. As the design moves forward the percentage of the pond to be filled may change to accommodate new information and stakeholder input. If possible, cut material from side channel excavations on the western floodplain of Gold Creek associated with restoration efforts in the creek should be utilized as fill for Heli's Pond, as it is close to the site and the cut material has characteristics very similar to that which was removed. Filling 75% of the depth of Heli's Pond would change the current pond by filling in the deepest portion of the pond on the northern end, while keeping the shallow southern side un-changed. During all by 4-6 weeks of the year the pond would be the same size as it is now, however lacking the deep part to the north. During the late summer the level of the ponds drops sufficient to fall below the shallow part of the pond, shrinking the pond down to the deep portion. Under the proposed condition this deep part would be filled, thus the pond by go completely dry in the late summer for up to several weeks.

4. STAKEHOLDER OUTREACH

Throughout the course of the assessment and design process that began in 2013, there have been multiple opportunities for stakeholders, landowners, and experts with local and general knowledge to review, comment, and critique assessment results and design considerations. Typically, these Technical Working Group (TWG) meetings were held at specific times following the distribution of draft reports and figures, and at critical restoration design milestones (conceptual designs, 30%, & 60%). There were also multiple meetings with the landowners of Gold Creek valley, specifically working to understand their values and concerns for incorporation in restoration designs.

KCT is a member of the Yakima Basin Bull Trout Working Group and has prepared multiple presentations to inform the group on project progress and present results of assessment and designs. Feedback from these meetings helped further understanding of the influences of seasonal dewatering due to anthropogenic impacts and restoration alternatives that will reintroduce natural processes for holistic restoration of lower Gold Creek valley. KCT, NSD, and other important stakeholders have worked hard to maintain open lines of communication and transparency about the restoration potential in lower Gold Creek valley from 2013 to present to ensure questions and concerns are answered and decisions are based on best available science.

During the data gap analysis; habitat, hydrologic, hydraulic, and geomorphic assessments; and conceptual design development from 2013 – 2015 there were a total of 4 TWG meetings. The first kickoff meeting discussed the data gap analysis and was used to guide NSD and KCT in the development of field work and data collection. The second and third TWG meetings were held at the conclusion of data collection and analysis following the 2013 and 2014 field seasons for review and comment on methods utilized and results discovered. The fourth and final TWG meeting at the conclusion of this phase of the project was held to review and receive comments on the conceptual restoration designs completed to decrease the extents and duration of seasonal dewatering, restore natural processes, to the extent possible, of lower Gold Creek valley, and improve habitat conditions for Gold Creek Bull Trout and other native fish populations.

On April 18th, 2015, there was a meeting with landowners to provide them an opportunity to review and provide feedback on the assessment and conceptual designs. KCT provided three presentations to the Bull Trout Working Group throughout this phase of the project. KCT also provided presentations to the 2014 and 2015 Science and Management Conference sponsored by the Yakama Nation on the Central Washington University campus. On May 6th, 2015 KCT met with USFS Staff from Mount Baker Snoqualmie National Forest, North Bend Ranger District (at the time, managers of Gold Creek Pond recreational area). KCT also prepared a poster for the 2015 Salvelinus Confluentus Curiosity Society conference held near Naches, WA.

In 2016, KCT and NSD began the second phase of design development to move instream restoration designs to 60% (permit ready). There were 3 TWG meetings held at 30% and 60% design development to receive comment and advance support for restoration designs. There were also multiple meetings with Ski Tur Valley Maintenance Association and other landowners in the valley to inform on restoration designs, model results, receive comments and understand their concerns. KCT and NSD received multiple comments and concerns from the landowners, developed a matrix to help respond and provide further feedback to the landowners. KCT presented to the Bull Trout Working Group at three of the regular meetings through 2016 and 2017. In February of 2016, KCT provided an update on the design and assessment work to the Upper Yakima Watershed Action Group. KCT also presented on the design and modeling work in the 2017 Science and Management Conference.

2018 to present was the third phase of design and permitting that was funded through Yakima Basin Integrated Plan and Bull Trout Enhancement funding. KCT engaged with landowners, stakeholders, and technical experts at various times to refine conceptual designs for Gold Creek Pond, Heli's Pond, Starwater drain line, and further instream restoration designs. A charrette with landowners and technical experts was convened in December of 2018 to determined alternative restoration designs for Gold Creek Pond. A smaller technical meeting was held in November of 2019 to understand recreational values found at the project site and ways to maintain existing access in Gold Creek Pond conceptual restoration alternatives. In January of 2019, NSD and KCT met with a small TWG to inform of the results of the lower Gold Creek assessment work that was completed in 2018. In March of 2019 KCT met and presented restoration assessment work and designs to the Central Cascades Winter Recreation Council to understand their values and answer questions regarding potential impacts to winter recreation.

KCT also engaged with Mid-Columbia Regional Fisheries Enhancement Group and the Bull Trout Task Force to provide information at Gold Creek Pond during the summer of 2019. In addition, KCT met with the Mountains to Sound Greenway Trust Board at a meeting in 2019 to inform them of restoration need in lower Gold Creek Valley.

KCT engaged with Forterra, a conservation landowner in lower Gold Creek Valley, to launch a partner website and provide for additional communication materials to better inform the public about the need for restoration. A short movie was professionally produced with partners including the Forest Service. Finally, new interpretive signs were developed and displayed at the Gold Creek Pond parking lot kiosk in partnership with the Forest Service and Conservation Northwest.

5. RECOMMENDATIONS

The breadth of work completed to date at Gold Creek has definitively concluded that Gold Creek Pond is a major contributor to dewatering in Gold Creek, which has been further exacerbated by historic over-widening of the channel and installation of a drain system on the eastern floodplain. The concept design alternatives developed for Gold Creek Pond are all shown to improve on the existing condition by raising groundwater elevations during the summer months sufficient to reduce the duration and extent of dewatering during the summer months. However, some of the alternatives are more successful than others in limiting dewatering in Gold Creek. While limiting dewatering is the primary intent and purpose of any proposed actions at Gold Creek Pond, other metrics should be considered in selecting a recommended alternative. A number of additional metrics were examined and ranked for each proposed concept design to attain a more complete picture of how each alternative would perform on the landscape. In general, the metrics included fall into categories of habitat uplift for Bull trout, habitat uplift for other species, risk to property, response time and ability to limit dewatering in Gold Creek. Once ranked each metric was given a weighting factor to account for higher priority metrics versus lower priority metrics.

Table 1 shows the metrics evaluated, ranking and weighted score for each concept design alternative developed. The rankings were based on best professional judgement considering all of the assessments and designs completed. Initial rankings were weighted based on their relative importance to judging the project as successful, with the highest weight given to the ability of the proposed design alternative in limiting the duration and extent of dewatering in Gold Creek. The results of the groundwater modeling were the primary data used rank each alternative for limiting dewatering in the channel, with the model resulting in the most wetted area in Gold Creek during the summer months chosen as the most likely to limit dewatering. A reliance on natural processes in achieving the project goals is important to consider as it will create new habitat over time as the site evolves, a self-maintaining design that will provide benefits well into the future. There are several habitat metrics specific to Bull trout that are critical to specific life history stages considered. Including stream length, temperature, number of pools and spawning habitat. More stream length, pools, and spawning habitat improves habitat conditions for Bull trout, while lower stream temperatures are required. Other species that will benefit from the proposed project (mammals, amphibians, birds, etc.) would find a more diverse landscape that includes an array of habitats, including wetlands and other habitats lacking in Gold Creek valley. The risk to property associated with each alternative is primarily from erosion and flooding, however higher groundwater elevations during the spring may also impact landowners. Floodplain connectivity relates to the ability of floodwaters to exit the channel and inundate the surrounding floodplain, a process that is currently cut-off at Gold Creek Pond. Alternatives that allow more flooding of the site are given higher ranking. While each alternative is predicted to limit summer dewatering in the channel, the amount of time it will take to realize these benefits will be a function of how long it takes the system to respond to actions at Gold Creek Pond. Alternatives that require more time are given a lower ranking relative to others with a faster response time. Similarly, shade along Gold Creek (10 yrs after implementation) resulting from planted riparian vegetation was used to rank the alternatives, those with more planted riparian edge received the highest rankings.

Each of these metrics were ranked and a weighted factor applied to score each of the proposed design alternatives. Based on this approach the highest ranked alternative is the Forested Wetland Complex with Creek

Integration, with a tie for second best between the Forested Wetland Complex and the Multi-Pond with Creek integration. The Multi-Pond alternative ranked the lowest of the alternatives evaluated. The Forested Wetland Complex with Creek Integration alternative outperformed the other alternatives primarily via improvements to Bull trout and other species habitats and improved floodplain connection. This recommended alternative provides the most potential for restoring the site back to something similar to that which was present prior to Gold Creek Pond, with the addition of Gold Creek meandering through the site. The ranking and selection has been conducted using the best available science at the time and is intended to provide decision makers with the professional opinion of NSD.

In addition to proposed actions at Gold Creek Pond, restoration actions are proposed in Gold Creek (NSD 2017b) and Helis Pond (NSD 2020c). NSD continues to support and recommend these additional actions to improve dewatering conditions in Gold Creek, as well as address degraded instream habitat conditions. Additionally, the drain system along Snowshoe Lane should be decommissioned or otherwise made to not convey groundwater to further limit dewatering in Gold Creek. The combination of these actions would restore the natural hydrology and flow to Gold Creek, realizing immediate benefits and providing a buffer to anticipated future changes resulting from climate change.

CONCEPT DESIGN ALTERNATIVE	LIMIT EXTENT & DURATION OF DEWATERING	RELIANCE ON NATURAL PROCESSES TO ACHIEVE GOALS OVER 10 YRS	HABITAT : BULL TROUT				HABITAT : OTHER SPECIES		RISK TO PROPERTY	FLOODPLAIN CONNECTIVITY IMPROVEMENT	ECOSYSTEM RESPONSE TIME	CHANNEL SHADE (IN 10 YRS)	TOTALS	RANK
			stream length	stream temperature	number of pools	spawning habitat	Wetlands	others						
FORESTED WETLAND COMPLEX	3	4	1	4	1	2	4	4	3	4	4	2	36	2
MULTI-POND	3	1	1	2	1	1	2	2.5	4	1	3	2	23.5	5
CREEK INTEGRATION	4	2	4	1	2	2	2.5	3	4	3	1	1	29.5	4
MULTI-POND AND CREEK INTEGRATION	2.5	3	3	3	3	3	3	4	4	2	2	3	35.5	3
FORESTED WETLAND COMPLEX AND CREEK INTEGRATION	2.5	5	5	5	4	4	5	5	3	5	5	3	51.5	1
WEIGHTING FACTOR	***3***	***1***	***1.5***	***2***	***1.5***	***1.5***	***1***	***0.5***	***1***	***1***	***1***	***1***		
FORESTED WETLAND COMPLEX	9	4	1.5	8	1.5	3	4	2	3	4	4	2	**46**	**2**
MULTI-POND	9	1	1.5	4	1.5	1.5	2	1.25	4	1	3	2	**31.75**	**5**
CREEK INTEGRATION	12	2	6	2	3	3	2.5	1.5	4	3	1	1	**41**	**4**
MULTI-POND AND CREEK INTEGRATION	7.5	3	4.5	6	4.5	4.5	3	2	4	2	2	3	**46**	**2**
FORESTED WETLAND COMPLEX AND CREEK INTEGRATION	7.5	5	7.5	10	6	6	5	2.5	3	5	5	3	**65.5**	**1**

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