TECHNICAL MEMORANDUM

To: Mitch Long, David Gerth, Kittitas Conservation Trust

From: David French, Tim Abbe, Mike Ericsson, Shawn Higgins

Date: May 31, 2013

Re: Gold Creek Habitat Assessment & Conceptual Design Task 1: Data Inventory & Data Gap Analysis

PROJECT BACKGROUND

The Kittitas Conservation Trust (KCT) has identified the lower 6.8 miles of Gold Creek above Keechelus Lake near Snoqualmie Pass as a candidate location for habitat restoration (Figure 1). The primary objective of the Gold Creek Project (Project) is to restore instream habitat for threatened Gold Creek Bull Trout (*Salvelinus confluentus*). The Project reach has been impacted by historic development and currently experiences significant dewatering during the summer months.

The purpose of the Project is to :

- Identify and describe the causal mechanisms contributing to seasonal dewatering of the channel
- Produce detailed conceptual design drawings to enhance habitat conditions for Gold Creek Bull Trout
- Provide scientific basis for how the concept design will achieve the Project goal

SITE LOCATION

Gold Creek is a tributary to Keechelus Lake, a reservoir adjacent to Interstate 90 near Snoqualmie Pass in Kittitas County, Washington.

EXISTING DATA

Information relevant to the Project was compiled by Natural Systems Design (NSD), KCT, and members of the Technical Working Group (TWG), in order to guide the assessments and conceptual design development. A data inventory compiled from state, federal, private, and non-profit agencies, as well as information provided by local stakeholders, was developed to determine the extent of existing knowledge related to the Project. Information gaps were noted and will direct the objectives of the proposed hydrologic, geomorphic, and habitat assessments. The current state of understanding of the causal mechanisms contributing to dewatering in Gold Creek is presented here, followed by a brief summary of additional information needed to complete the project goals.

Data Sources

All pertinent, available data from state, federal, private, and non-profit agencies as well as information provided by local landowners and stakeholders was compiled into a project database. A total of 150 references related to Gold Creek and the surrounding area make up this database (Appendix A), which encompasses historical communication documents, aerial imagery, relevant scientific studies, land use history, climate, regional geology, and channel morphology. In addition to references provided by KCT and TWG, NSD retrieved data from:

- WA Department of Natural Resources
- WA Department of Ecology
- WA Department of Transportation
- WA Department of Fish & Wildlife
- US Forest Service
- US Geological Survey
- US Bureau of Reclamation
- US Fish & Wildlife
- University of Washington
- Central Washington University
- Geo REF Database
- Science Direct Database
- Personal correspondence records (KCT, WDFW, UW, CWU, BoR, Menconi, Trotter, others)

Gold Creek Watershed

Gold Creek drains a 14.3 square mile (9,122 acre) watershed in the Cascade Mountain range, flowing for approximately 8 miles before entering Keechelus Lake near Interstate 90 (Figure 2) (Craig 1997, Wissmar & Craig 2004, USFS 1998). The drainage basin ranges from 2,507 to 6,933 feet (ft) above sea level (total relief of 4,426 ft.) (Wissmar & Craig 2004) with an average annual precipitation of 87.6 inches and mean temperatures ranging from 33 – 52 degrees Fahrenheit (Western Regional Climate Center 2013). The lower reach of Gold Creek (river mile (RM) 0 – 1.85) is a low-gradient (1%), braided channel flowing through a broad, alluvial valley of highly-permeable sand and gravel (USFS 1998, Collins 1997). The average bankfull width in this reach is 160 ft and the valley is 500 ft wide in some areas, greatly reducing tributary inputs of sediment and large woody debris (LWD) (Collins 1997). The middle reach (RM 1.85 – 3.1) is more confined, with average bankfull and valley widths of 50 and 100 ft, respectively (Collins 1997). This reach averages a 3% gradient, and is composed of pool-riffle segments dominated by cobble and boulders (USFS 1998, Collins 1997). The upper reach (RM 3.1-7.1) is a high-gradient (5%) channel of step-pool segments underlain by boulders and bedrock (Collins 1997). The upper reache is moderately confined, with an average bankfull width of 40 ft and a mean valley width of 100 ft. Fish passage is impeded by a bedrock cascade segment and a waterfall at RM 5.3 and 7.1, respectively (Craig 1997, Collins 1997). Stream discharge measurements in lower Gold Creek range from 12.3 cfs in mid-August to 19.9 cfs in late September and a peak flow of 331 cfs was measured in mid-June (Thomas 2001). In recent years, channel dewatering in the lower and middle reaches has been observed between mid-July and late September (Craig 1997, Mayo 2003).

Land Use History & Associated Impacts

Placer mining, timber harvest, residential development, Keechelus Lake reservoir impoundment, natural geomorphic processes (landslides, channel migration, etc), and the construction of I-90 have all contributed to a changing landscape in lower Gold Creek. Timber removal likely began during construction of a mining tramway into the valley in the late 1800s (USFS 1993) and continued into the 1990s until formation of the Alpine Lakes Wilderness. Construction of the dam impounding Lake Keechelus was completed in 1917, raising the high water level nearly 61 feet and inundating Gold Creek 2.5 miles upstream from its historic mouth (Deichl, et al. 2011). Gold Creek Pond now occupies a gravel borrow pit, which was excavated to a depth of 60 feet (Craig 1997) throughout construction of I-90 in the 1970s and 1980s before being reclaimed as a visitor's area in the early 1990s. The pond is fed by cold groundwater seeps (Craig 1997) and its depth reportedly exceeds that of the water table (Ehlert 1997). In 1992, the Washington Department of Transportation and the U.S. Forest Service converted the drainage outlet of the pond to a spawning channel for resident and adfluvial fish and began replanting the surrounding area with additions of topsoil, seed, and fertilizer (Mayo 2003). This spawning channel rejoins Gold Creek approximately 1800 ft downstream from the pond outlet (USFS 2012). A second, smaller pond further to the Northeast (RM 1.9) was constructed some time in the late-1990s in what appears to be a historic alignment of Gold Creek (Anderson 2000).

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). Historical aerial images clearly show a reduction in forest canopy throughout the watershed and Ehlert (1997) estimates a 90% reduction in shaded area over the course of 50 years (Figure 3) (Deichl, et al. 2011; Meyer 2012). The presence or absence of LWD can influence the formation of deep pools in the creek, which serve as refugia for fish during periods of low-flow or higher water temperatures (Meyer 2002). LWD is viewed as a key component to the recovery of Gold Creek's lower reaches (Plum Creek Timber Company 1997, Unknown 2012). An avalanche in 2008 near RM 4 delivered a significant volume of LWD to the channel, which appears to be accumulating sediment at the upstream end of the debris deposits. The discharge in this reach is insufficient for downstream transport of the woody material. Several landslide hazard areas within the watershed have been identified by Washington Department of Natural Resources, but there is no evidence of recent mass wasting events near the channel (Figure 2). Potential contributors to Gold Creek dewatering also include a domestic sewer line adjacent to the Ski Tur development, and a water resource well located northeast of Gold Creek Pond, which feeds a 30,000 gallon reservoir for domestic use (WA Dept. of Ecology 1983).

Hydrologic Changes

Segments of Gold Creek have gone dry in recent years during the summer months. Dewatering typically occurs between RM 0.6 and 1, but extends as far as RM 2.5 in some years (Trotter 2012). Dewatering has been reported to occur as early as July 16 (Thomas 2001). A 2001 study conducted by the Bureau of Reclamation showed no correlation between Keechelus reservoir drawdown and the water level in Gold Creek Pond, but reported that dewatering of the channel may occur when the surface level of the pond is below that of the channel (Didricksen). Because the water surface at the upstream end of the pond is at a lower elevation than the adjacent creek channel, hyporheic flow into the pond is likely to occur (Meyer 2012). Craig (1997) reported that dewatering of Gold Creek occurs when stream discharge is less than the base flow (4.6 cfs) in the spawning channel draining Gold Creek Pond. The temperature of the pond outlet (at the inlet to the spawning channel) is 7°Fahrenheit warmer than water seeping into the northern end of the pond, presumably due to cold groundwater seeps and hyporheic flow from the creek, and solar warming of the ponded water (Plum Creek Timber Company 1997, Craig & Wissmar 1994). Coarse sediment inputs due to management-induced reductions in bank stability have resulted in channel widening and increased infiltration rates (Cupp 1997). During full pool of the Keechelus reservoir (Spring), Gold Creek experiences a backwater effect to RM 0.5 during the same time when Spring freshet events capable of transporting sediment occur. This has resulted in sediment deposition and bar formation at the extent of backwater effects (Bakke 2012). Low-gradient streams with highly permeable substrate are prone to subsurface flow where they encounter an alluvial fan (Winter, et al. 1999), which is an analog for conditions at this location.

Although it is beyond the scope of the Project budget to assess, climate change may be a contributing factor to channel dewatering. Glacial recession has been observed in the North Cascades for the past decade (Fountain, et al. 2009) and more precipitation in the form of rainfall is projected in the Northwest due to a higher frequency of atmospheric rivers or 'pineapple expresses', which will likely result in reductions to snowpack and summer base flows (Neiman, et al. 2011). An estimated 1.6 inches of rainfall per month is needed to maintain surface flow in Gold Creek, and below normal precipitation is likely to result in further channel dewatering (Wissmar & Craig 1997). A study conducted in Western Washington estimated the drainage area required for perennial streamflow to be 2.4 acres (ac) in areas with basaltic substrate and 0.5 ac in watersheds underlain by Astoria sandstone (Jaeger, et al. 2007). Thus, the basaltic Gold Creek watershed (9122 ac) should be of sufficient size to maintain perennial flow under normal meteorological conditions.

Spatial Data

The U.S. Forest Service conducted stream surveys on portions of Gold Creek in 1993, 1998, and 2012. These reports contain surface information, water temperature, channel cross sections, and a thalweg profile for select reaches. LiDAR data for the watershed was collected by Watershed Sciences, Inc. in 2011. Landslide hazard areas for the region were identified by the Washington Department of Natural Resources and the GIS dataset was completed in June 2010. Aerial imagery of the watershed exists for select years from 1944 through 2011 from various sources (Appendix B). Tax parcels and land ownership data from 2012 was downloaded from the Washington Department of Natural Resources. Well log information for 48 geotechnical borings in the vicinity of the I-90 bridge crossing and for 2 water resource wells within the Gold Creek valley were obtained from the Department of Ecology.

DATA GAPS

The existing data inventory revealed several missing components that are considered critical to completion of the project goals:

- Temporal and spatial variability of surface and groundwater elevations
- Stream discharge/hydrograph
- Channel substrate size and distribution
- Precipitation gage data
- Spatial distribution of erosional/depositional areas
- Spatial distribution of LWD and associated geomorphological features
- Hydraulic modeling
- Spatial arrangement of pools and other habitat features

Attachments:

Figure 1 – Gold Creek Project Site Map
Figure 2 – Gold Creek Watershed Map
Figure 3 – Historic Aerial Imagery 1942 – 1975
Appendix A- Reference List for Gold Creek
Appendix B- Gold Creek Aerial Imagery Inventory

CC :

REFERENCES

Anderson, E., 2000. Gold Creek Observations 6142000 Correspondence. Washington Department of Fish & Wildlife. B. Renfrow, T. Clausing, W. Essman. Washington Department of Fish & Wildlife.

Bakke, P., 2012. Recommendations for Gold Creek Habitat Assessment, U.S. Fish & Wildlife Service.

Collins, B., 1997. Appendix E- Channel Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.

Craig, S.D., 1997. Habitat Conditions Affecting Bull Trout, Salvelinus confluentus, Spawning Areas Within the Yakima River Basin, Washington. M.S., Central Washington University, Ellensburg, WA, 86 pp.

Craig, S.D., Wissmar, R.C., 1994. Bull Trout in Gold Creek, WA: Recommendations. University of Washington Fisheries Research Insitute,.

Cupp, C.E., 1997. Appendix F- Fish Habitat Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.

Deichl, C., Hackett, A., Pierson, D., Sandberg, J., Slavick, J., 2011. Gold Creek: Development to Restoration. U.S. Forest Service, U.S. Department of Agriculture, Okanagan/Wenatchee National Forest, University of Washington.

Didricksen, K., 2001. Gold Creek Study Summary. U.S. Bureau of Reclamation. Upper Columbia Area Office. Gold Creek Pond Memorandum.

Ehlert, H., 1997. Appendix G and Appendix H- Water Quality Module and Water Supply-Public Works Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.

Fountain, A.G., Hoffman, M.J., Granshaw, F., Riedel, J., 2009. The'benchmark glacier'concept does it work? Lessons from the North Cascade Range, USA. Annals of Glaciology, 50(50), 163-168.

Jaeger, K.L., Montgomery, D.R., Bolton, S.M., 2007. Channel and perennial flow initiation in headwater streams: management implications of variability in source-area size. Environmental Management, 40(5), 775-786.

Mayo, T.M., 2003. Gold Creek Bull Trout Correspondence. U.S. Forest Service, U.S. Department of Agriculture. Wenatchee National Forest. E. Anderson. Washington Department of Fish & Wildlife.

Meyer, W., 2002. De-Watering Causes: The Effects of Seasonal Stream De-Watering on Three Age Classes of Bull Trout, Salvelinus confluentus. M.S., Central Washington University, Ellensburg, WA.

Meyer, W., 2012. Habitat Assessment & Conceptual Design Powerpoint Presentation, Yakima Basin Fish & Wildlife Recovery Board.

Neiman, P.J., Schick, L.J., Ralph, F.M., Hughes, M., Wick, G.A., 2011. Flooding in Western Washington: The Connection to Atmospheric Rivers*. Journal of Hydrometeorology, 12(6), 1337-1358.

Plum Creek Timber Company, L.P., 1997. Overview. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company, L.P.

Thomas, J.A., 2001. Hydrologic and Water Temperature Investigation of Tributaries to Keechelus Reservoir. Final Report, U.S. Fish & Wildlife Service, Mid-Columbia River Fishery Resource Office.

Trotter, P., 2012. Gold Creek Bull Trout, Salvelinus confluentus: Their Life Cycle and Use of Habitat While in the Creek. Draft, Natural Systems Design.

United States Forest Service, 1993. U.S.F.S 1992-1993 Gold Creek Stream Survey Summary Report, United States Department of Agriculture, Mount Baker Snoqualmie National Forest.

United States Forest Service, 1998. Gold Creek Stream Survey Executive Summary, United States Department of Agriculture, Mount Baker Snoqualmie National Forest.

United States Forest Service, 2012. Gold Creek Lands Survey, U.S. Department of Agriculture, Mount Baker Snoqualmie National Forest.

Unknown, 2012. Field Tour Notes. September 11, Gold Creek, WA.

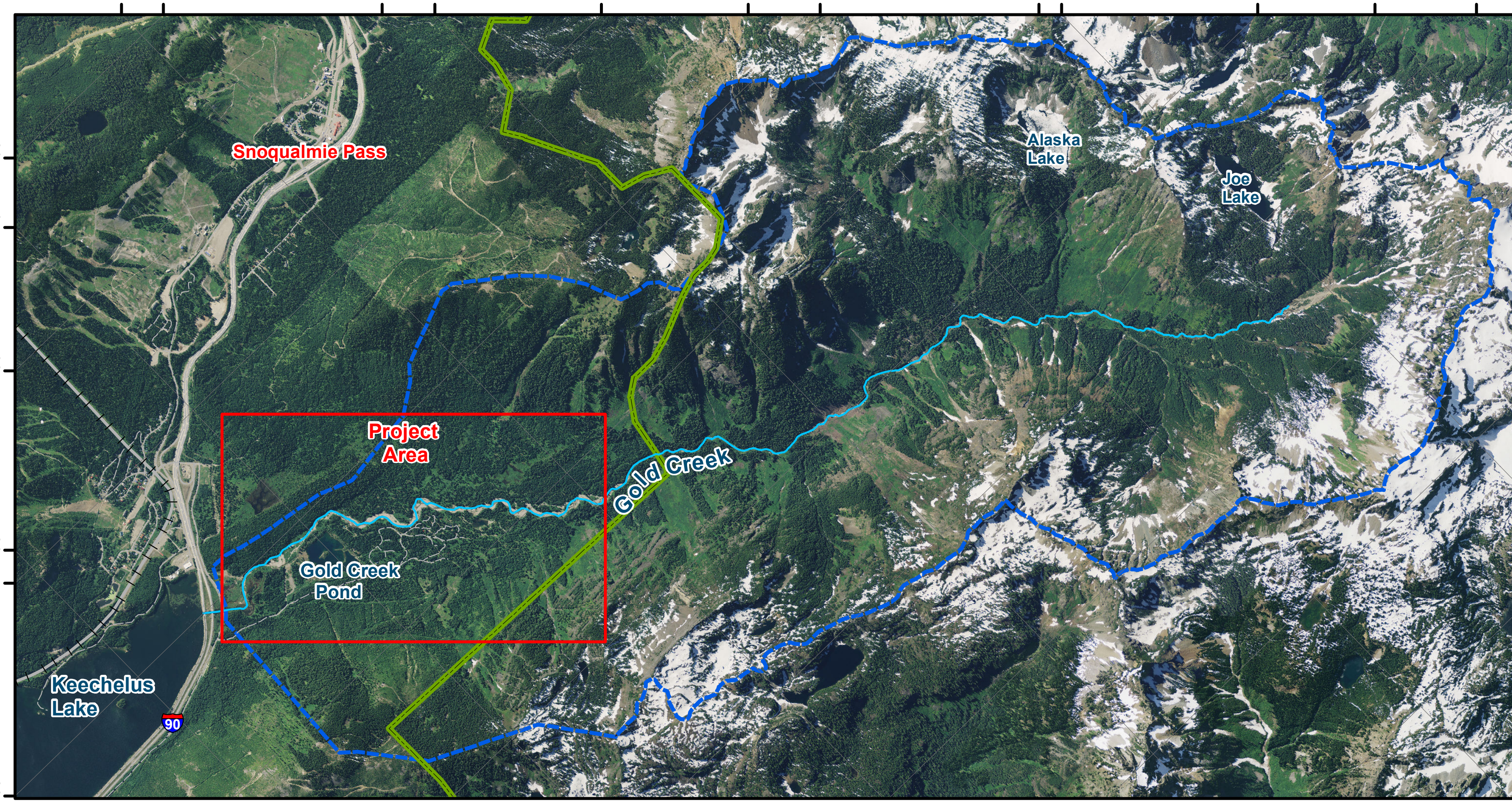
Washington Department of Ecology, 1983. Water Well Report. Reintree Corp & J.P McGowan, Kittitas County, Washington.

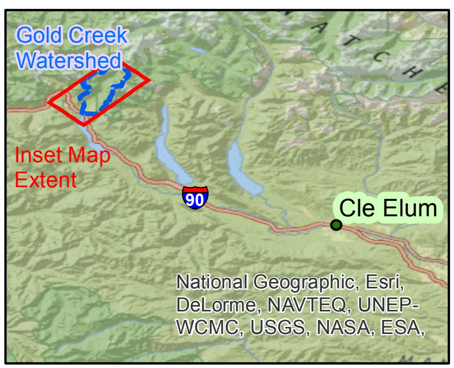
Western Regional Climate Center, 2013. Period of Record Monthly Climate Summary Stampede Pass WSCMO, Washington Station #458009 - Stampede Pass, Washington, Desert Research Institute, Reno, NV.

Winter, T.C., Harvey, J.W., Franke, O.L., Alley, W.M., 1999. Chemical Interactions of Ground Water and Surface Water, Ground Water and Surface Water a Single Resource U.S. Geological Survey, , Denver, CO, pp. 22-39.

Wissmar, R., Craig, S., 2004. Factors affecting habitat selection by a small spawning charr population, bull trout, Salvelinus confluentus: implications for recovery of an endangered species. Fisheries Management and Ecology, 11(1), 23-31.

Wissmar, R.C., Craig, S., 1997. Bull Trout Spawning Activity, Gold Creek, Washington, University of Washington, Seattle, Fisheries Research Institute.





Legend

- Main Channel
- Roads
- Railroad
- Wilderness Boundary
- Watershed Boundary

Feet

0 2,000 4,000 8,000

Data sources:
USDA National Agriculture Imagery Program
USGS National Hydrography Dataset

Kittitas Conservation Trust

Natural Systems Design
P.O. Box 15609
Seattle, WA 98115

Gold Creek
Project Site Area

Northeast of Snoqualmie Pass
Kittitas County, Washington

FIGURE 1 – Gold Creek Project Site Map

Gold Creek Habitat Assessment & Conceptual Design

Natural Systems Design
P.O. Box 15609
Seattle, WA 98115

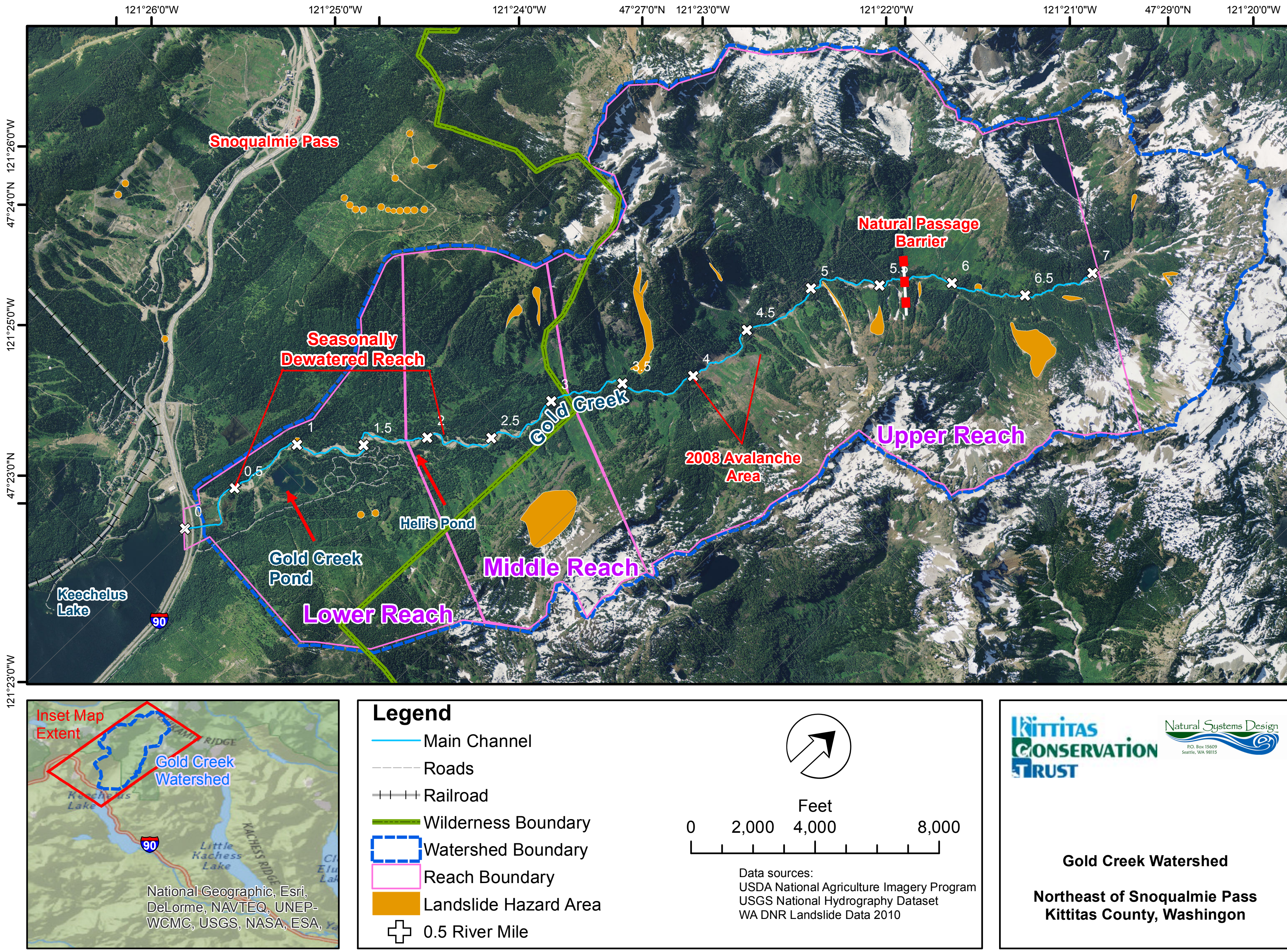


FIGURE 2 – Gold Creek Watershed Map

Gold Creek Habitat Assessment & Conceptual Design

Natural Systems Design
P.O. Box 15609
Seattle, WA 98115

Source: Meyer, W., 2012. Habitat Assessment & Conceptual Design Powerpoint Presentation, Yakima Basin Fish & Wildlife Recovery Board.

FIGURE 3 – Historic Aerial Imagery 1942 - 1975

Gold Creek Habitat Assessment & Conceptual Design

Natural Systems Design
P.O. Box 15609
Seattle, WA 98115

APPENDIX A

Reference List for Gold Creek Habitat Restoration & Conceptual Design

Updated: May 17, 2013 by David French

Anderson, E., 1996. Biological Data Field Notes. 2, Washington Department of Fish & Wildlife.

Anderson, E., 1996. Biological Data Field Notes. 3, Washington Department of Fish & Wildlife.

Anderson, E., 1996. Biological Data Field Notes. 1, Washington Department of Fish & Wildlife.

Anderson, E., 1998. Bull Trout Presence in Local Streams Correspondence. K. Wolf, J. Cummins, B. Essman.

Anderson, E., 1998. Keechelus Dam Safety Issues & Reservoir Restrictions. Washington Department of Fish & Wildlife. Region 3 Headquarters. K. Wolf.

Anderson, E., 1998. Keechelus Fish Passage & Mitigation. Washington Department of Fish & Wildlife. C. Leigh, K. Wolf, J. Cummins.

Anderson, E., 1999. Gold Creek - Arctic Char Correspondence. Washington Department of Fish & Wildlife. B. Henkel.

Anderson, E., 1999. Gold Creek Reply Correspondence. Washington Department of Fish & Wildlife. B. Curtis, J. M, B. Henkel.

Anderson, E., 2000. Gold Creek Observations 6142000 Correspondence. Washington Department of Fish & Wildlife. B. Renfrow, T. Clausing, W. Essman. Washington Department of Fish & Wildlife.

Anderson, E., 2000. Trip Report 1-24-2000 Correspondence. Washington Department of Fish & Wildlife. W. Henkel, J. M.

Bakke, P., Review of Preliminary Design Proposal U.S. Fish & Wildlife Service. Lacey, WA. Joanne.

Bakke, P., 2012. Recommendations for Gold Creek Habitat Assessment, U.S. Fish & Wildlife Service.

Bambrick, F.D., 1998. Environmental Issues Opportunities Related to Dam Repair-Replacement. Keechelus Dam Safety Project 12/15/98 White Paper, Washington Department of Fish & Wildlife, South Central Region.

Bortleson, G.C., Washington . Department of, E., Geological, S., 1976. Reconnaissance data on lakes in Washington. Dept. of Ecology, Tacoma, Wash.

Box, D., 1993. The Ongoing Saga-- Regulations. Washington Department of Wildlife. F.R.P. Managers.

Brown, L., 1994. Gold Creek Bull Trout Spawning Surveys, Washington Department of Fish & Wildlife, .

Brown, L.G., 1989. Gold Creek Pit Pond and Interprative Site Correspondence. U.S. Department of Agriculture. U.S. Forest Service North Bend Ranger District. R. Edwards. Washington Department of Wildlife.

Brown, L.G., 1992. Gold Creek Pond - Channel Hydraulic Project - Construction Update Correspondence. Washington Department of Wildlife. F. Goetz. U.S. Forest Service, U.S. Department of Agriculture.

Brown, L.G., 1992. Management Guide For the Bull Trout Salvelinus confluentus (Suckley) on the Wenatchee National Forest. Draft, Washington Department of Fish & Wildlife, Wenatchee, WA.

Brown, L.G., 1993. Additional Bull Trout Age/Growth Data Correspondence. E. Anderson, C. Burley, P. Hahn.

Brown, L.G., 1993. Gold Creek Bull Trout- 1993 Spawning Surveys Correspondence. U.S. Department of Wildlife. North Bend Ranger District, Mt. Baker/Snoqualmie National Forest. K. Chang.

Brown, L.G., 1993. Physical Measurement of Adfluvial Bull Trout Redds from 1984 Correspondence. Washington Department of Wildlife. Yakima Office. J. Cummins, E. Anderson, C. Burley, P. Hahn. Fisheries Management.

Carl, File and Photo Description.

Carl, Problem Reach Photo.

Carl, 2000. Surface Photo- September 30.

Carl, 2004. Aerial Photographs 2004-2007.

Carl, 2006. Surface Photos- July 24, Gold Creek, WA.
Carl, 2007. Surface Photos- March 21.
Carl, 2007. Surface Photos- May 21.
Carl, 2007. Survey Photos- October 15.
Carl, 2008. Gold Creek Avalanche Imagery.
Carl, 2009. Surface Photos- June 15, Gold Creek, WA.
Clausing, T., 1995. FPA: 8262 T22N, R11E, Section 11 Chikamin Vista Properties. Washington Department of Fish & Wildlife. L. Quackenbush. Washington Department of Natural Resources.
Clausing, T.A., 1995. FPA: 8262 T22N, R11E, Section 11 Chikamin Vista Properties- Application Clarification Correspondence. Washington Department of Fish & Wildlife. L. Quackenbush. Washington Department of Natural Resources.
Collins, B., 1997. Appendix E- Channel Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.
Craig, S., 1994. Redd Locations in Gold Creek 1994 Correspondence. University of Washington. Fisheries Research Institute. E. Anderson. Washington Department of Fish & Wildlife.
Craig, S., 1994. Trap & Tag Bull Trout 1994 Correspondence. University of Washington. School of Fisheries. E. Anderson. Washington Department of Fish & Wildlife.
Craig, S., 1999. Gold Creek and Keechelus Kokanee- Reply Correspondence. U.S. Fish & Wildlife Service. Endangered Species Division. E. Anderson. Washington Department of Fish & Wildlife.
Craig, S.D., 1997. Habitat Conditions Affecting Bull Trout, Salvelinus confluentus, Spawning Areas Within the Yakima River Basin, Washington. M.S., Central Washington University, Ellensburg, WA, 86 pp.
Craig, S.D., Wissmar, R.C., 1994. Bull Trout in Gold Creek, WA: Recommendations. University of Washington Fisheries Research Insitute,.
Cupp, C.E., 1997. Appendix F- Fish Habitat Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.
Davis, J., 1969. Meeting Notes - Borrow Pit, Gold Creek 2720- Special Uses, U.S. Forest Service, U.S. Department of Agriculture, Wenatchee National Forest.
Deichl, C., Hackett, A., Pierson, D., Sandberg, J., Slavick, J., 2011. Gold Creek: Development to Restoration. U.S. Forest Service, U.S. Department of Agriculture, Okanagan/Wenatchee National Forest, University of Washington.
Didricksen, K., 2001. Gold Creek Study Summary. U.S. Bureau of Reclamation. Upper Columbia Area Office. Gold Creek Pond Memorandum.
DiLeonardo, C.G., 1987. Structural evolution of the Smith Canyon Fault, northeastern Cascades, Washington, United States.
Drake, W.E., 1972. Gold Creek Pit Site Correspondence. U.S. Forest Service, U.S. Department of Agriculture. Cle Elum Ranger District, Wenatchee National Forest. Washington Department of Game.
Drake, W.E., 1973. Gold Creek Pit Site Meeting Confirmation. U.S. Forest Service, U.S. Department of Agriculture Cle Elum Ranger District, Wenatchee National Forest. M. Thomas. Washington Department of Game.
Eaton, B.C., 2006. Bank stability analysis for regime models of vegetated gravel bed rivers. Earth surface processes and landforms : the journal of the British Geomorphological Research Group., 31(11), 1438-1444.
Eaton, B.C., Church, M., Millar, R.G., 2004. Rational regime model of alluvial channel morphology and response. Earth Surf. Process. Landforms Earth Surface Processes and Landforms, 29(4), 511-529.
Ehlert, H., 1997. Appendix G and Appendix H- Water Quality Module and Water Supply-Public Works Module. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company.

Fisher, J.P., 2004. Salmon, Steelhead, and Bull Trout in Water Resources Areas 37, 38 & 39: An Interim Strategy for Stock Recovery and Project Prioritization. Yakima River Basin Salmon Recovery Board Lead Entity, Entrix, Inc., Olympia, WA.

Fountain, A.G., Hoffman, M.J., Granshaw, F., Riedel, J., 2009. The'benchmark glacier'concept does it work? Lessons from the North Cascade Range, USA. Annals of Glaciology, 50(50), 163-168.

Frederick, D.C., 1995. FPA: 8262 T22N, R11E, Section 11 Chikamin Vista Properties- Technical Review Correspondence. U.S. Department of the Interior. Fish and Wildlife Service Western Washington Office. L. Quackenbush. Washington Department of Natural Resources.

Game, W.D.o., 1980. Fish Survey Info 1980. Lake Keechelus.

Gjertson, J.O., 1972. Gold Creek - Borrow pit - Special Uses. U.S. Forest Service, U.S. Department of Agriculture. Wenatchee National Forest.

Goetz, F.A., 1994. Distribution and Juvenile Ecology of Bull Trout (Salvelinus confleuntus) in the Cascade Mountains. M.S., Oregon State University, Corvallis, OR.

Goodwin, C.L., Westley, R.E., Washington . Dept. of Fisheries. Research, D., 1967. Limnological survey of Kachess, Keechelus, and Cle Elum reservoirs : summary report. State of Washington, Dept. of Fisheries, Research Division, [S.l.].

Gualtieri, J.L., Thurber, H.K., Miller, M.S., McMahan, A.B., Federspiel, F.F., 1975. Mineral Resources of Additions to the Alpine Lakes Study Area, Chelan, King, and Kittitas Counties, Washington. Open-file report 75-3, U.S. Geological Survey, U.S. Bureau of Mines, U.S. Department of the Interior.

Hamman, J., Hamlet, A.F., Fuller, R., Grossman, E., Effects of Projected Twenty-First Century Sea Level Rise, Storm Surge, and River Flooding On Water Levels in the Skagit River Floodplain and Estuary.

Henkel, W., 1999. Dialogue on Gold Creek Correspondence. Washington Department of Fish & Wildlife. E. Anderson. Washington Department of Fish & Wildlife.

Jaeger, K.L., Montgomery, D.R., Bolton, S.M., 2007. Channel and perennial flow initiation in headwater streams: management implications of variability in source-area size. Environmental Management, 40(5), 775-786.

James, P., 2002. Gold Creek - Trap Correspondence. Central Washington University. E. Anderson. Washington Department of Fish & Wildlife.

Lakes, W., 2005. Fishing Reports for Lake Keechelus 1996-2005.

Lee, M., 1998. Keechelus Dam Repair Could Cost $10 Million, Tri-City Herald, Kennewick, WA.

LEE, S., Hamlet, A., 2011. Effects of Climate Change on Natural and Regulated Flood Risks in the Skagit River Basin and Prospects for Adaptation, AGU Fall Meeting Abstracts, pp. 1036.

Lester, D., 1998. Dam's Price Tag-- $10 Million, Herald-Republic, Yakima, WA.

Lester, D., 1998. Keechelus Dam Dangerously Damaged, Herald-Republic, Yakima, WA.

Lester, D., 1998. What if... Herald-Republic, Yakima, WA.

Lowery, J.W., 1979. Memorandum of Understanding- Gold Creek Barrow Pit. U.S. Forest Service, U.S. Department of Agriculture. Cle Elum Ranger District. D. Ranger. North Bend Ranger District.

Lyon, T.E., 1979. Reclaimation Plans for Gold Creek Pit Correspondence. Washington Department of Transportation. Engineer's Field Office. L.G. Brown. Washington Deparment of Game.

Mankowski, J., 1988. Forest Practice Application0 FP01-3686 Correspondence. Washington Department of Fish & Wildlife. L. Charlton. Washington Department of Natural Resources.

Mayo, T.M., 2003. Gold Creek Bull Trout Correspondence. U.S. Forest Service, U.S. Department of Agriculture. Wenatchee National Forest. E. Anderson. Washington Department of Fish & Wildlife.

Meyer, W., 2002. De-Watering Causes: The Effects of Seasonal Stream De-Watering on Three Age Classes of Bull Trout, Salvelinus confluentus. M.S., Central Washington University, Ellensburg, WA.

Meyer, W., 2004. Gold Creek fishing - poaching update Correspondence. Washington Department of Fish & Wildlife. E. Anderson. Washington Department of Fish & Wildlife.

Meyer, W., 2012. Habitat Assessment & Conceptual Design Powerpoint Presentation, Yakima Basin Fish & Wildlife Recovery Board.

Meyer, W.R., 2002. The Effects of Seasonal Stream De-Watering on Three Age Classes of Bull Trout, Salvelinus confluentus. M.S., Central Washington University, Ellensburg, WA.

Mongillo, P., Faulconer, L., Washington . Dept. of, G., 1980. Yakima fisheries enhancement study : final report. Washington Dept. of Game, Olympia.

Moya, A.M.R., 1989. Information on Gold Creek Pond Correspondence. U.S. Forest Service, U.S. Department of Agriculture. North Bend Ranger District. L.G. Brown.

Mulick, C., 1998. Dam Repairs to Draw Down Yakima River Irragation Water, Tri-City Herald, Kennewick, WA.

Mumford, J., 1998. Keechelus Dam: Summary of Risk Reduction Options for Near-Term Operations. U.S. Bureau of Reclamation, Yakima Field Office, Yakima, WA.

Neiman, P.J., Schick, L.J., Ralph, F.M., Hughes, M., Wick, G.A., 2011. Flooding in Western Washington: The Connection to Atmospheric Rivers*. Journal of Hydrometeorology, 12(6), 1337-1358.

Orsborn, J.F., 1991. Engineering Survey and Design of the Gold Creek Pond Outlet Channel for Spawning Enhancement. U.S. Forest Service, U.S. Department of Agriculture, River Masters Engineering, Inc., North Bend Ranger District, Mt. Baker-Snoqualmie National Forest.

Parker, R., 1998. Risk Reduction Being Implemented at Keechelus Dam Correspondence. U.S. Bureau of Reclamation. Upper Columbia Field Office.

Plum Creek Timber Company, L.P., 1995. 1994 Washington Bull Trout Survey Results. Washington Department of Fish & Wildlife.

Plum Creek Timber Company, L.P., 1997. Overview. Keechelus Lake- Mosquito Creek Watershed Analysis, Plum Creek Timber Company, L.P.

Ralph, F.M., Neiman, P.J., Kiladis, G.N., Weickmann, K., Reynolds, D.W., 2010. A multi-scale observational case study of a Pacific atmospheric river exhibiting tropical-extratropical connections and a mesoscale frontal wave. Monthly Weather Review.

Reiss, K.Y., Thomas, J., Anderson, E., Cummins, J., 2012. Yakima Bull Trout Action Plan. Final Report, Yakima Basin Fish & Wildlife Recovery Board, U.S. Fish & Wildlife Service, Washington Department of Fish & Wildlife.

Reiss, Y., 2009. Meeting Notes- October 20, Upper Yakima Watershed Action Group.

Renfrow, B., 1996. Potential Passage Barrier Gold Creek Correspondence. Washington Department of Fish & Wildlife. Region 3. R. Klatt.

Renfrow, B., 2000. Gold Creek ...revisited Correspondence. Washington Department of Fish & Wildlife. E. Anderson. Washington Department of Fish & Wildlife.

Renfrow, B.D., 1990. Proposed Gold Creek Pond Interpretive Site Development Correspondence. Washington Department of Fish & Wildlife. Region 3. R.V. Edwards. North Bend Ranger District, U.S. Forest Service, U.S. Department of Agriculture.

Renfrow, B.D., 1998. Keechelus Dam Correspondence. Washington Department of Fish & Wildlife. T. Clausing. Washington Department of Fish & Wildlife.

Rennie, R., 1966. Report of DOT utilitzing 800,00 tons of Gravel from the Gold Creek Drainage Correspondence. Washington Department of Fisheries. Stream Improvement & Hydraulics. D. Stuckey.

Roeder, T., 1998. Problems at Keechelus Dam? Answers Expected Soon, Herald-Republic, Yakima, WA.

Salminen, E., 1997. Hydrologic Change Assessment for the Keechelus/Mosquito Creek Watershed Analysis, Plum Creek Timber Company.

Ski Tur Valley, 1999. Ski Tur Cabin & Lot Owners Map.

Smith, D.L., Johnson, G., Williams, T., 2006. Natural streamflow estimates for watersheds in the lower Yakima River. SP Cramer & Associates, Sandy, OR.
Stanford, J.A., Snyder, E.B., Lorang, M.N., Whited, D.C., Matson, P.L., Chaffin, J.L., 2002. The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, Washington. US Department of the Interior, Bureau of Reclamation, Yakama Nation, Flathead Lake Biological Station, University of Montana, Polson, MT.
Tabor, R.W., V.A. Frizzell, J., Booth, D.B., Waitt, R.B., 2000. Geologic Map of the Snoqualmie Pass 30 x 60 Minute Quadrangle, Washington. U.S. Geological Survey, Denver, CO.
Tappel, P., 2012. Cold Creek Fish Passage Project Memorandum. Fisheries Engineers, Inc. . Kittitas Conservation Trust.
Thomas, J.A., 2001. Hydrologic and Water Temperature Investigation of Tributaries to Keechelus Reservoir. Final Report, U.S. Fish & Wildlife Service, Mid-Columbia River Fishery Resource Office.
Transportation, W.D.o., 1979. Asahel Curtis I/C to Summit- Westbound Paving Utimate Reclamation Plans, Olympia, WA.
Trotter, P., 2012. Gold Creek Bull Trout, Salvelinus confluentus: Their Life Cycle and Use of Habitat While in the Creek. Draft, Natural Systems Design.
U.S. Bureau of Reclamation, 1998. Keechelus Dam Press Conference. PN-1203, U.S. Department of the Interior, Pacific Northwest region.
U.S. Fish & Wildlife Service, 1998. Bull Trout Facts (Salvelinus confluentus).
U.S. Forest Service, Mt Baker - Snoqualmie National Forest Interpretive Displays. U.S. Department of Agriculture.
U.S. Forest Service, Ultimate Site Plan- Gold Creek Pond. U.S. Department of Agriculture.
U.S. Forest Service, 1989. Vision for Gold Creek Pond- Proposed Site Plan, U.S. Forest Service, U.S. Department of Agriculture, Mt. Baker-Snoqualmie National Forest.
U.S. Forest Service, 1998. Memorandum - Meeting to Intitiate Keechelus Lake Bull Trout Recovery Plan. Wenatchee National Forest, Cle Elum Ranger District, Mount Baker-Snoqualmie National Forest, North Bend Ranger District. U.S. Bureau of Reclamation, Central Washington University, Washington Department of Fish & Wildlife.
U.S. Geological Survey, 1989. Snoqualmie Pass, Washington 7.5 Quad Topographic Map. U.S. Geological Survey, Denver, CO.
United States Environmental Protection Agency, National Eutrophication Survey, Washington Department of Ecology, Washington National Guard, 1977. Report on Keechelus Lake, Kittitas County, Washington : EPA Region X. Corvallis Environmental Research Laboratory ; Environmental Monitoring & Support Laboratory, Corvallis, Or.; Las Vegas, Nev.
United States Forest Service, 1993. U.S.F.S 1992-1993 Gold Creek Stream Survey Summary Report, United States Department of Agriculture, Mount Baker Snoqualmie National Forest.
United States Forest Service, 1998. Gold Creek Stream Survey Executive Summary, United States Department of Agriculture, Mount Baker Snoqualmie National Forest.
United States Forest Service, 2012. Gold Creek Lands Survey, U.S. Department of Agriculture, Mount Baker Snoqualmie National Forest.
Unknown, Gold Creek Dewatered Reaches- Map.
Unknown, Gold Creek Landowners Map.
Unknown, Gold Creek Pond Photo.
Unknown, Management Objectives, Design Criteria, & Requirements.
Unknown, 1967. Keechelus Lake Angler Counts.
Unknown, 1989. Gold Creek Redd Survey Logs 1981 - 1989.
Unknown, 2000. Stream Dewatering Imagery.
Unknown, 2002. Gold Creek Steam Survey Data, Gold Creek, Washington.

Unknown, 2008. Bull Trout Redds Map.
Unknown, 2008. Gold Creek Project Area Bull Trout Redds-Map.
Unknown, 2011. Channel Changes 1942-2011 Imagery.
Unknown, 2011. Gold Creek Problem Statement. August 23, 2011, Yakima Basin Fish & Wildlife Recovery Board.
Unknown, 2012. Avalanche Google Earth Imagery.
Unknown, 2012. Field Tour Notes. September 11, Gold Creek, WA.
Unknown, 2012. Gold Creek Vicinity Map.
Unknown, 2012. Project Proposal for Planning Project: 12-1306 Gold Creek Habitat Assessment & Conceptual Design.
Van Kirk, R.W., Naman, S.W., 2008. Relative Effects of Climate and Water Use on Base-Flow Trends in the Lower Klamath Basin1. JAWRA Journal of the American Water Resources Association, 44(4), 1035-1052.
Washington Department of Ecology, 1983. Water Well Report. Reintree Corp & J.P McGowan, Kittitas County, Washington.
Washington Department of Ecology, 2008. Log of Test Boring. Well ID 560059, Washington State Department of Transportation, T22N R11E S1 NW NW.
Washington Department of Ecology, 2011. Gold Creek Well Logs, U.S. Forest Service, U.S. Department of Agriculture, Cle Elum Ranger District.
Washington Department of Fish & Wildlife, 1993. Proposal - Gold Creek, Gold Creek Pond and Outlet Channel - Closed Waters (Fishing). R3-5.
Washington Department of Fish & Wildlife, 1999. Chelan Hatchery Plants Report- Keechelus, Washington Department of Fish & Wildlife, Hatcheries Program.
Washington Department of Fish & Wildlife, 2013. Bull Trout. Washington Department of Fish & Wildlife, Olympia, WA.
Washington Department of Wildlife, 1992. Hydraulic Project Approval - Instream Habitat Structures U.S. Forest Service, U.S. Department of Agriculture.
Washington State Department of Transportation, 2008. Chapter 3: Affected Environment and Consequences. I-90 Snoqualmie Pass East Project Environmental Impact Statement, Washington State Department of Transportation, Yakima, WA.
Washington State Department of Transportation, 2008. Environmental Impact Statement Summary. I-90 Snoqualmie Pass East Project, Washington State Department of Transportation, Yakima, WA.
Washington State Department of Transportation, URS Corporation, Washington State Library Electronic Publications, 2008. I-90 Snoqualmie Pass East project final technical memorandum 1-- Gold Creek Bridges : 2007 geotechnical analysis and reporting. Washington State Dept. of Transportation, [Olympia, Wash.].
Washington State Parks & Recreation Commission, Washington State Library Electronic Publications, 2005. Gold Creek Sno-Park groomed trail system [Motorized trails]. Washington State Parks and Recreation Commission, Olympia, WA.
Watershed Sciences Inc., 2012. LiDAR Remote Sensing: Cle Elum River & Gold Creek, Washington. Delivery 2, Cardno Entrix, Seattle, WA.
Weiler, W.J., 1995. FPA: 8262 T22N, R11E, Section 11 Chikamin Vista Properties- Mini-IDT Correspondence. Washington Department of Fish & Wildlife. R. Reed. Washington Department of Natural Resources.
Weiler, W.J., 1995. Gold Creek Forest Practice Application Correspondence. Washington Department of Fish & Wildlife. S. Spaulding. U.S. Fish & Wildlife Service.
Western Regional Climate Center, 2013. Period of Record Monthly Climate Summary Stampede Pass WSCMO, Washington Station #458009 - Stampede Pass, Washington, Desert Research Institute, Reno, NV.

Winter, T.C., Harvey, J.W., Franke, O.L., Alley, W.M., 1999. Chemical Interactions of Ground Water and Surface Water, Ground Water and Surface Water a Single Resource U.S. Geological Survey, , Denver, CO, pp. 22-39.

Wissmar, R., Craig, S., 2004. Factors affecting habitat selection by a small spawning charr population, bull trout, Salvelinus confluentus: implications for recovery of an endangered species. Fisheries Management and Ecology, 11(1), 23-31.

Wissmar, R.C., 1994. Proposal- Bull Trout Life History Requirements, Gold Creek, Washington. University of Washington. Fisheries Research Institute. D. Hann. Washington Department of Fish & Wildlife.

Wissmar, R.C., Craig, S., 1997. Bull Trout Spawning Activity, Gold Creek, Washington, University of Washington, Seattle, Fisheries Research Institute.

Wissmar, R.C., Craig, S., 1997. Gold Creek Study Area Map. In: G.C. Bull trout spawning activity, Washington, (Ed.). University of Washington, Fisheries Research Institute.

Yakima Basin Fish & Wildlife Recovery Board, 2009. Bull Trout Action Plan: Gold Creek.

Yakima Basin Fish & Wildlife Recovery Board, 2009. Gold Creek Assessment Meeting- June 3, Yakima Basin Fish & Wildlife Recovery Board.

APPENDIX B

Gold Creek Aerial Imagery Inventory

Compiled by S. Higgins 05/06/2013, Updated by D. French 05/13/2013

Imagery downloaded from USGS Earth Explorer database

Date	Scale*	Hz Rez	Georef	Type
9/10/1957	47200		N	BW
9/4/1958	40000		N	BW
6/22/1977	63666		N	CIR
8/9/1979	80000		N	BW
9/23/1985	24000	1 m	N	CLR
9/27/1994	12000	1 m	Y	BW
7/25/1998	12000	1 m	Y	BW
4/1/2006	12000	0.5 m	Y	CLR
8/26/2011	12000	1 m	Y	CLR

Imagery available from UW map library (not yet obtained)

Date	Scale*	Hz Rez	Georef	Type	Source
1944	20000		N	BW	USACE
1962	12000		N	BW	USFS
1965	60000		N	BW	Pacific Aerial Surveys
1970	15840		N	BW	USFS
1974	24000		N	BW	WA DNR
1975	15840		N	BW	USFS
1991	12000		N	BW	WA DNR

Imagery available from WSDOT (not yet obtained)

Date	Scale*	Hz Rez	Georef	Type	Source
1957				BW	WSDOT
1963				BW	WSDOT
1977				BW	WSDOT

Imagery downloaded from CWU

Date	Scale*	Hz Rez	Georef	Type	Source
9/24/1954	20000		N	BW	USDA
9/24/1954	20000		N	BW	USDA

Imagery from Carl Menconi

Date	Scale*	Hz Rez	Georef	Type	Source
6/12/2004			N	CLR	Menconi
12/27/2004			N	CLR	Menconi
7/28/2005			N	CLR	Menconi
10/13/2007			N	CLR	Menconi