Ship Creek — Anchorage, Alaska

Fish Passage Improvement Alternatives Analysis
Past Elmendorf and Fort Richardson Dams

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1 Introduction

This study considers fish passage improvement alternatives, at a conceptual level, past two of the four dams along Ship Creek. The Elmendorf dam is located on the Elmendorf Air Force Base (EAFB) approximately 1,600-ft upstream from Reeve Boulevard and is comprised of two sheet pile dams about 130-ft wide, with a total height of approximately 12-ft. The Elmendorf dam is a complete barrier to upstream fish passage. The Fort Richardson dam is located at the Alaska Department of Fish and Game (ADF&G) fish hatchery on the Fort Richardson Army Base (FRA) approximately 3,000-ft downstream from the Glenn Highway and is a single concrete structure about 5-ft high by 80-ft wide. The locations of the dams are shown on Sheet 1 (Appendix 7.1). The Elmendorf and Fort Richardson dams are run of the river structures that were constructed by the Military to divert water from Ship Creek for cooling of their respective power plants. ADF&G was able to use warm effluent from the power plants to supply fish hatcheries at these two locations to aid in accelerating growth rates of fish. The Elmendorf power plant has been dismantled. The Fort Richardson power plant is currently not in operation, though future plans may include reactivating the power plant. ADF&G is in the process of upgrading to new hatchery facilities which would not be dependent on the water or heat supplied by the dams or power plants. Since the dams are no longer needed, ADF&G is investigating alternatives for restoring fish passage past the dams to access upstream habitats.

This study was funded with $70,000 from a grant provided by the U.S. Fish and Wildlife Service (USFWS) to ADF&G. The purpose of the study was to develop alternatives to improve fish passage conditions past the Elmendorf and Fort Richardson dams. A range of alternatives were developed in an attempt to address some or all of current and future uses by stakeholders. In addition, the impacts of each alternative to aquatic habitat, stream and infrastructure stability and ground water resources is conceptually evaluated and discussed. The volume of sediments contained in the dam impoundments is estimated. A search of known contamination issues was conducted as well as sampling and analysis of impounded sediments for the presence of likely contaminants.

ADF&G contracted with the team of Inter-Fluve, Inc. (Inter-Fluve), USKH, Inc. (USKH) and Shaw Alaska, Inc. (Shaw) to conduct the study. Inter-Fluve headed up the investigation group and provided aquatic habitat mapping, stream hydrology and hydraulic analysis and led the effort to developed alternatives. USKH conducted site survey, structural inspections, prepared recommendations for structural modifications, a synopsis of potential permit requirements and finalized conceptual level construction cost estimates. Shaw conducted the contamination information review, sampling of impounded sediments for contamination analyses and conducted groundwater investigations, data recording and modeling.

Through a conceptual level investigation and alternatives and feasibility analysis, methods to provide fish passage past these two barriers were explored. The alternatives analysis involved the readily available primary stakeholders - ADF&G, Military and USFWS. Additional stakeholders and the public will be involved by ADF&G after completion of this study. A suite of alternatives to provide fish passage past the two dams were considered, discussed and developed to provide a spectrum of actions that would meet some or all of the goals - including full, partial or no removal of the dams. Selection of a preferred alternative at each dam will be dependent on multiple factors including:

- Stakeholders' current and future use; and, goals for each dam.
- Provision of fish passage.
- Impacts to aquatic/fish habitat, geomorphic stream process, channel stability, adjacent ground water table and infrastructure.
- Cost.

Specific questions the study has been asked to address include:

- What would the creek look like without the dam/spillway?
- Sediment load: How much sediment is behind the dams, are they contaminated, how will sediment transport impact channel geomorphology and stability?
- Fish passage: Will fish passage improve and what type of construction is necessary?
- How will water chemistry and surface and groundwater hydrology be affected?
- Provide recommendations for a cost effective solution that meets project goals?

Given the available budget and the number of tasks to be completed at each dam, alternatives and supporting analysis are necessarily prepared to the conceptual level only. Though not an EA, EIS or NEPA document, this study is intended to serve as a tool to facilitate discussions by stakeholders for improvement of fish passage and access to Ship Creek aquatic habitats. The results of the study are intended to enable an informed decision making process in comparing alternatives and selecting a preferred alternative. It should be stressed that the alternatives are intended to provide a spectrum of actions that are possible. The final preferred alternative and action may differ from what is presented here. Following selection of a preferred alternative, additional analysis of feasibility, cost, construction and permitting logistics and schedule should be completed before moving forward with funding for design and construction of a preferred alternative.

2 Site Meetings/Field Investigations/Survey

In order to gain an understanding of issues at the Elmendorf and Fort Richardson dams, site investigations and meetings were conducted including the following.

Site meeting. A site review was conducted with ADF&G personnel to tour the site and gain site specific knowledge.

Interviews. Readily available primary stakeholders were interviewed about their current and future use, function and management of each dam. ADF&G, Sport Fish Division personnel included area management biologist and hatchery managers. Representatives from Elmendorf Air Force Base (EAFB) and Fort Richardson Army (FRA) Base included civil engineering and environmental personnel. Meetings and discussions were used to develop goals of the various stakeholders specific to each dam as appropriate for: 1) stability of the stream and adjacent infrastructure, 2) use of the dams, and 3) potentially impacted stream reaches and ground water resources. During these interviews, initial concepts for alternatives were discussed through a design charette (brain storming) process. The results of these discussions were incorporated into the development and discussion herein of alternatives.

Existing data. Meetings with stakeholders provided information on known existing data. Available existing information was used to the extent possible. Some of the existing data used in this study included: as-built drawings for the dams, U.S. Geological Survey (USGS) stream flow data, U.S. Army Corps of Engineers (USACE) flood estimates, published aquifer data and contamination reports.

Site survey. Basic site topography and bathymetry locations were identified by Inter-Fluve. USKH surveyors collected the requested survey information. Survey data included stream thalweg (lowest elevation of the bed in cross section) profile, cross sections, coarse topography near the dams and general detail on the dam structures. These survey data were used to develop a conceptual level 1-dimensional HEC-RAS hydraulic model of the existing and alternatives condition for each dam. Survey data were also used to estimate the volume of sediment wedges deposited upstream of the dams.

Sediment sampling – Grain size distribution (GSD). Size distributions of sediments observed along the stream bed were photographically documented at a number of locations. A measuring tape was laid on the surface for scale and could provide the basis of a "photographic pebble count" at later phases. Data collection was conducted through out the study reach. Representative photos are included in Appendix 7.2.

Sediment sampling – Contamination investigation. Readily available existing studies and reports were investigated for known contamination issues that might influence the sediments at the two dams. In addition, one sample of sediment deposited in the impoundment of each dam was collected by Shaw. The sample was then submitted for laboratory analysis. Methods, analysis and results are summarized in a memorandum prepared by Shaw included in Appendix 7.4. **Based on the laboratory analysis for the target contaminants, no contaminates were identified which exceeded the Alaska Department of Environmental Conservation's regulatory limits. Due to the limited number of samples collected, the sampling results should be regarded as a screening tool only, and may not be representative of actual sediment conditions at the dam sites.**

Aquatic/fish physical habitat inventory. Aquatic physical habitat conditions along reaches of Ship Creek that, early in the investigation, were anticipated to be potentially impacted by the alternatives were documented through detailed hand mapping and photographs. The study reach and physical habitat features are indicated in Appendix 7.2. The alternatives presented below are located well within the habitat mapping coverage. These habitat maps provide a basis for comparison of habitat impacts associated with the alternatives.

Structural evaluation. Available drawings for the two dams were researched and located by USKH staff. These drawings were used in support of the structural evaluation by USKH's structural engineer. The evaluation of existing dam structures conducted by USKH was based on visual inspection and simple non destructive testing and was intended to determine the general condition and provide an opinion of service life of the infrastructure and feasibility for fish passage retrofit. A memorandum summarizing the structural inspection by USKH is included in Appendix 7.3.

Ground water. An investigation of ground water resources was conducted by Shaw. Existing information was researched. Six Hobo data loggers were provided by Inter-Fluve for use to collect continuous ground water levels. Five loggers were deployed down wells and the sixth was kept above ground to collect barometric pressure data for correcting water depths by Shaw at the Fort Richardson dam. Loggers recorded continuously from June 14, 2006 through October 26, 2006. Corresponding continuous surface water records from gage number 15276000 from May 1, 2006 through October 31, 2006 were provided by the USGS. Logger locations and recorded well levels and stream flows are summarized in Appendix 7.6. A memorandum summarizing the ground water data collection and modeling by Shaw is included in Appendix 7.5.

3 Project Goals

Through discussions with representatives of ADF&G and the Military a set of goals were developed. The goals for the two dams are essentially similar and were lumped into one set as noted below.

ADF&G goals:

- Improve fish passage.
- Improve existing operations (e.g. sediment flushing from intake structures, access of fish into the brood pond, water supply).
- Provide or increase stream stability while minimizing loss of existing habitats.
- Reduce or minimize operation and maintenance requirements (e.g. debris, sedimentation, icing and ice flows).
- Accommodate future plans for a new fish hatchery and/or visitor facility. However, specifics of the new facilities are not known at this time.

Military goals:

- Dams' original purpose was run of the river diversion of cooling water for power plants at each location. The Elmendorf power plant has been dismantled. The Fort Richardson power plant is currently moth balled but may be reactivated.
- Minimize risk to existing infrastructure.
- Minimize O&M requirements.
- Minimize Bird Aircraft Strike Hazard (BASH) risk
- Minimize risk of fish borne nuisances such as disease or decomposition contamination of shallow ground water wells; and, carcass smell and presence.
- Minimize potential for intrusion by salmon poachers, and accompanying security risks
- Minimize impact to golf course, family housing and Family Camp areas from fish carcasses
- Minimize bear-human conflicts.
- Evaluate changes to contaminant plumes based on changed hydrologic gradient. (Note: evaluation of changes in groundwater gradients and contamination plumes is beyond the scope of this alternatives analysis, but would be required during later phases of study or design.)

4 Methodology

4.1 Hydrology

Flow event peak discharge. Hydrology estimates prepared by the U.S. Army Corps of Engineers (USACE) was used for this analysis as summarized and provided by USFWS (W. Rice, personal communication). The Corps analyzed Ship Creek in 1980 using the closest USGS gage - about 1.3-miles downstream of the Elmendorf dam – (USGS gage 15276570 SHIP C BL POWER PLANT AT ELMENDORF AFB AK). This gage has a period of record from October 1, 1970 through January 31, 1981. From the USACE report *Special Flood Hazard Information, Ship Creek, Elmendorf AFB*, (1980) the flows for the 10-, 20-, 50- and 100-year were available and used in this study.

Extrapolate to smaller events. The 2- and 5-year event peak flows are also of interest. These flows were estimated by extrapolation from the USACE estimates of peak flows. The extrapolation was based on plots of discharge on a linear scale versus probability of a particular event occurring (1/Tr) on probability scale. This plot is included in Appendix 7.6.

DA ratio Q's to dams. The magnitudes of flows were adjusted to the locations of the dams through a straight drainage (DA) ratio. Drainage areas at each dam were estimated from nearby USGS gages. Four USGS gages were identified which bracketed the two dams and had published drainage areas. Latitude and longitude coordinates were used to locate each gage on the USGS quadrangle topographic maps. An approximate distance along Ship Creek was measured between dams and the adjacent gages. An estimate of drainage area tributary to the dam was then approximated from neighboring gage area through linear interpolation using a ratio of stream distance between the dam and respective gage. Based on approximations of drainage area, the USACE flow estimates were then adjusted to the location of both dams through a drainage area ratio. This analysis is shown in Appendix 7.6.

A series of lower discharges were included in the hydraulic model to capture a range of stream flows.

A summary of flows included in the HEC-RAS models is shown in the following table.

Event	Peak Discharge (cfs)	Discharge estimate at Elmendorf Dam (cfs) D.A. ratio = 0.998	Discharge estimate at Fort Richardson Dam (cfs) D.A. ratio = 0.918
2-Yr	725 cfs[2]	724	665
5-Yr	1,060 cfs[2]	1058	973
10-Yr	1,300 cfs[1]	1298	1193
20-Yr	1,500 cfs[1]	1498	1377
50-Yr	1,800 cfs[1]	1797	1652
100-Yr	2,000 cfs[1]	1997	1836

Notes:

1 – USACE report (1980)

2 – Extrapolated from USACE estimates.

Summer 2006 flows. Continuous surface water records from gage number 15276000 from May 1, 2006 through October 31, 2006 were provided by the USGS. These data were provided for comparison to observed high water marks to validate the HEC-RAS models. Comparisons of the continuous USGS surface water data to the logged ground water levels are shown in Appendix 7.6.

Geomorphic. Channel forming flows were estimated based on observations and survey of bank full features in the field. Stream reaches were identified that appeared to be geomorphically stable, with features included in the stream cross section surveys. The bank full features were identified through grade breaks, location of vegetation and depositional features. The HEC-RAS predictions of flow depths were then used to extract a flow that reasonably matched to these features. Considering multiple cross sections it appears from this simplified analysis that a geomorphically significant flow ranged somewhere between 100 and 300-cfs. This flow is less than a 2-year event – a commonly used rule of thumb for channel forming flow - and should be further considered during later design phases.

Cross sections that appeared to not be influenced by infrastructure and geomorphically stable were used to estimate width and depth templates. At Elmendorf cross sections 2, 10 and 12 had a width of approximately 60-ft and a depth of about 1.5-ft. At Fort Richardson cross sections 2 and 12 had a width of about 60- to 65-ft and maximum and average depths of about 2.8-ft and1.6-ft, respectively. Cross sections are shown in Appendix 7.7.

Fish Passage flows. The ADF&G fish passage MOA indicates that the 2-day duration of the 2-year hydrograph is the design flow for fish passage. A 2-year hydrograph was not located during this conceptual level study. As a surrogate, the 90-percent exceedance discharge criteria used by Washington Department of Fish and Wildlife (WDFW) was used for this study. A flow duration curve was developed from average daily flows at USGS gage 15276000 (Ship C nr Anchorage AK) and is shown in Appendix 7.6. Later design phases should identify or develop the 2-year hydrograph for Ship Creek to determine the 2-day duration discharge in order to be consistent with ADF&G criteria.

4.2 Stream Hydraulics

Hydraulic conditions at both dams were evaluated using the U.S. Army Corps of Engineers HEC-RAS (version 3.1.2) one-dimensional open channel hydraulic model. For both dams, a conceptual level model was developed for existing conditions based on site cross section and topographic survey data. Channel and over bank roughness were estimated based on engineering judgment and methods of roughness partitioning (Arcement and Schneider, 1989). The existing conditions models were then copied and modified to represent each alternative condition. Cross section locations, summary profiles and cross sections are presented in Appendix 7.7.

ADF&G staff monitored and staked in the field high water levels from May through October 2006. The highest of these high water levels was observed during October 10, 2006 and was surveyed in the field. The associated stream flow was determined from the USGS continuous flow gage records. The high water mark was compared to predictions from the HEC-RAS model. Results were favorable and no further calibration was completed at this conceptual level.

The status of FEMA flood insurance study, mapping and hydraulic modeling were investigated by USKH. FEMA delineations do exist for Ship Creek. However, the delineation is mapped only outside of Federal lands. Delineations within the Elmendorf Air Force Base and Fort Richardson Army Base were not located. The alternatives analysis is based on site specific conceptual level modeling. No revisions to FEMA mapping are included in this phase. Included in Appendix 7.7 are plots of the 100-year water surface elevation profiles for existing and alternative conditions. Compared to existing conditions some local reaches of Ship Creek will have increases in 100-year water surface elevations for a number of the alternatives.

4.3 Sediment Transport/Geomorphology/Stream Stability

Geomorphic conditions of Ship Creek from near the Elmendorf Air Force Base and downstream were investigated and reported by Montgomery Watson (2001) and ReTec (2004). These reports were reviewed.

Observations of geomorphic characteristics were included in the field investigation. Channel bed and banks are comprised of alluvial material. Riparian vegetation includes willows and alders growing in a thin organic mantle which overlays the alluvial material. Erosion removes the underlying bank alluvium, undercutting this vegetation and organic mantle causing slumping of the banks and lateral migration. Historically, Ship Creek was likely very dynamic in change to geomorphic features, location and geometry. Large wood would be expected to have a profound impact on geomorphic conditions. This dynamic character of Ship Creek is beneficial in creating and rejuvenating aquatic habitats.

Sediment conditions were observed during the field investigation. Specifics at each dam are included in Section 5.1.1 and 5.2.1 for Elmendorf and Fort Richardson, respectively. In general, deposition of sediment, or aggradation, creates gravel bars with coarser armor. These armored bars are more erosionally resistant than the banks, leading to bank erosion and lateral migration. Sediment retention at the dams interrupts supply of sediment to downstream reaches. The stream then erodes material from the bed and banks to satisfy its sediment transport potential with a typical response being downcutting or incision of the stream bed and banks.

In addition to field observations and photo documentation, aerial photos were obtained from AeroMap for the two dams. From these photos, the geomorphic templates described in Section 5.1.1 and 5.2.1 were confirmed as being appropriate as templates.

Partial or full removal of the dams removes the grade control function which each dam currently provides. The Elmendorf dam has a total height of about 12-ft. The Fort Richardson dam has a total height of about 5-ft. Removal of grade control is expected to result in a headcut, or erosion of the stream bed, that migrates upstream with time. Erosion of the sediment wedge accumulated within each impoundment is not expected to have detrimental channel stability responses. However, further reductions in grade control elevations are likely to lead to downcutting of the stream bed. Thus, the alternatives evaluated apparently stable upstream cross sections and slopes. These slopes were then extended through the length of the impoundments to estimate the profile of the sediment wedges. For the alternatives involving partial or full removal of the dams, grade controls were included to match to this slope extension in an effort to reduce the potential for head cuts to migrate upstream. Detailed evaluation and design for channel stability will be necessary during later design phases.

4.4 Fish Habitat Inventory

The goal of the fish habitat inventory for the Ship Creek Fish Passage Improvement Project was to map the aquatic habitat and stream geomorphic conditions currently present in defined reaches of Ship Creek. The mapping encompassed sections of the stream predicted to extend both upstream and downstream of anticipated limits of the hydraulic or construction impacts that may result from the implementation of any of the fish passage alternatives examined by this project. (Refer to Appendix 7.2)

The mapping was conducted by physically walking the subject reaches of Ship Creek and creating scaled sketches of the main channels and side channel conditions present at the time of the survey. Since this mapping procedure requires wadeable water depth, the field work was conducted in the spring after most of the ice and snow were melted but before the higher flows of late spring and summer. The field work for this inventory was conducted over a three day period, May 10-12, 2006.

The lengths of the habitat features were measured with a hip chain. The measurements started from a structure that was easily identifiable on aerial photographs, thus allowing for the accurate mapping of the field data onto aerial base maps for each dam site. The width of the features were estimated and drawn to scale in the field book (refer to scans of field book, Appendix 7.2). The primary habitat features mapped were pools, riffles, glides/runs and areas of sub-surface flow. These individual habitat units are defined as:

- *Pools.* Pools are areas with very low velocities with residual depths greater than 0.5 foot. Water surfaces are flat.
- *Riffles.* Riffles have obvious surface turbulence and are typically shallow water less than a foot deep with low to moderate slopes (<4%). Water velocities are greater than 1f/s
- *Glide/run.* Habitat units commonly referred to as glides and runs are lumped into one unit designation. This is done to improve the repeatability of designation of this habitat unit. Glide/runs have some surface turbulence due to water velocities greater than that for pools and are typically deeper than riffles. Water velocity is less than 1f/s to distinguish from riffles. Water surfaces are very gently sloping.
- *Sub-surface.* If the entire flow goes sub-surface (across the entire wetted width), the unit is classified as sub-surface.

Water depth was periodically measured across the channel width and noted in the field book. When possible, the depth of each pool was measured and noted in both the field book and on the final maps. Water depth is supplemented by the survey collected for the HEC-RAS hydraulic model and is available in Appendix 7.7.

Additionally, a number of other stream features were noted in the field and incorporated onto the detailed field sketches. These features included:

- Substrate types. This delineation was not finely detailed, and was sometimes limited by accessibility. The noted types include silt, sand, gravels, cobble, and large rock. A number of photographs of the bed substrate, with a tape for scale, were taken and are included in the figures.
- Bank type. This was primarily limited to noting areas of vertical and eroding banks.
- Riparian vegetation. This was documented with photography.
- Gravel bar location. The type and extent of vegetation on the bar was also noted
- Bank armoring locations.
- Large woody debris locations.
- Tributary locations.
- Man made structures such as dams, bridges, rock vanes and pipelines.

- Areas of vegetative bank stabilization projects. This includes the spruce tree revetment downstream of the Elmendorf dam and the root wad revetment upstream of the Fort Richardson dam.

The mapped reaches were extensively documented with photographs. The location and directional aspect of each photograph was noted on the field drawings. Representative photos are included with the figures in Appendix 7.2.

The primary habitat features were converted from the field book sketches to CAD sketches using Autodesk Design Review, and were then incorporated into the final CAD drawing shown in Appendix 7.2. The sketches were drawn to scale on the AeroMap aerial photographs of both dam sites. If necessary, minor adjustments to feature widths and lengths were completed to align with the structures visible on the aerial photographs.

4.5 Sediment Contamination Investigation, Sampling & Analysis

Readily available existing studies and reports were investigated for known contamination issues that might influence the sediments at the two dams. In addition, one sample of sediment deposited in the impoundment of each dam was collected by Shaw from an accessible location within the impoundment. The sample was then submitted for laboratory analysis. Methods, analysis and results are summarized in a memorandum prepared by Shaw included in Appendix 7.4.

Shaw concludes that based on the laboratory analysis for the target contaminants, no contaminates were identified which exceeded the Alaska Department of Environmental Conservation's regulatory limits. Due to the limited number of samples collected, the sampling results should be regarded as a screening tool only, and may not be representative of actual sediment conditions at the dam sites.

4.6 Ground Water Investigations and Modeling

An investigation of ground water resources was conducted by Shaw. The reader is referred to Appendix 7.5 for the Shaw memorandum summarizing the data collection, modeling and results.

Additional information has been provided in comments by EAFB staff about a superfund site on EAFB and existing groundwater data near the Elmendorf dam. Though these issues are beyond the scope of this study, they must be addressed in future phases. Details are included in comments by Melissa Markel, in Appendix 7.10.

5 Alternatives Analysis

Through discussions with stakeholders on current/future use of the two dams and goals of the final project, five alternatives were developed to a conceptual level at each dam. The alternatives are intended to present a suite of possibilities. The preferred alternatives and final project may differ from concepts presented here. Alternatives fall into five general categories:

1. Do nothing – baseline conditions.
2. Construct a side channel for fish to bypass the dams.
3. Rehabilitate existing fish ladder or retrofit the dams with a new fish ladder.
4. Partial removal of dams and/or construction of a roughened channel to decrease jump height.
5. Full removal of the dams from hydraulic influence and construction of a roughened channel.

The development of alternatives was intended to address issues of fish passage, sustainable stream process and habitats, stream and infrastructure stability, operations and maintenance (O&M) and cost. Considerations in developing features of each alternative include the following:

- <u>Geomorphology</u> – Appropriate geomorphic conditions along Ship Creek are incorporated to the extent possible in the alternatives. The anticipated geomorphic response to each alternative is described.
- <u>Channel/infrastructure stability</u> – Existing infrastructure would be potentially impacted by stream response to the alternatives. Therefore, the alternatives include measures to account for stream stability and minimize impact to adjacent infrastructure.
- <u>Fish habitat/culture</u> –Merely providing passage past both dams will provide access to miles of upstream habitat. The ability to include fish habitat locally at both dams was explored to the extent practicable. Fish passage is evaluated based on jump heights as described in Powers and Orsborn (1985). The trajectory of a fish leaping at an obstacle is plotted based on burst speed of fish and simple physics. For adult Chinook and Coho in good condition, jump heights of 3- to 4-ft are easily passable. Jump heights of 4- to 6-ft would be moderately passable. Jump heights of 6- to 7.5-ft would be difficult to pass. Jump heights greater than about 7.5-ft exceeds the performance curve and would be assumed to be rarely passed to impassable. In addition, pool depth is a factor in jumping performance. Though no specific literature was identified, a rule of thumb seems to be a pool with depth 25-percent greater than the jump height would not be limiting. Hatchery managers indicate that returning hatchery fish have undergone 98- to 99-percent cull rates and would have near similar athletic ability of their wild counterparts (D. Kiefer, ADF&G, personal communication). For the fourth alternative, a jump height of 3-ft was selected as a target as being easily passable by both wild and hatchery healthy adult Chinook and Coho salmon.

- Ground water resources – changes in stream levels have anecdotally been a factor in yield of nearby shallow groundwater wells. The stream hydraulic analysis of existing and alternatives' conditions provided water surface elevations along the stream which were used as a boundary condition in the ground water model to assess relative impact to water table elevations.
- Civil infrastructure – existing and future structures will influence feasible alternatives. USKH's structural engineer conducted a visual inspection of the existing dams; and provided a professional opinion of service life and feasibility of retrofitting existing structures.
- Permitting – depending on features of the alternatives, permitting requirements would be similar at both dams. A memorandum of permitting requirements has been prepared by USKH and is included in Appendix 7.8.

A narrative of alternatives features, anticipated passage conditions, geomorphic response, pros/cons and relative cost are described in the sections below. This conceptual level alternatives analysis is intended to serve as a planning level tool for selection of a preferred alternative by stakeholders to best meet their goals and the Ship Creek ecosystem and geomorphic environment.

5.1 Alternatives analysis – Elmendorf Dam

5.1.1 Existing conditions

The existing dam is comprised of two sheet pile weirs. Upstream of each weir is a gravel-cobble channel. The lower weir requires a jump height of between 7.5- to 8-ft, depending on flows, for fish to pass. Considering the leap trajectories described in Section 5, it is anticipated that the lower weir would be nearly a complete barrier to healthy adult Chinook and Coho salmon to pass. This is consistent with observations. The upper weir requires a jump height of 5.5- to 6-ft for fish to pass and would be moderately difficult to pass. A general rule of thumb used by fisheries biologists is that if the pool is 25-percent greater than the jump height the pool is not the limiting factor (Koonce, pers. comm.). Based on USKH measurements during the structural evaluation, the maximum depths of the lower and upper scour pools 5.7-ft and 8-ft, respectively. Thus, the upper weir would not be pool-limited for passage. The lower pool would be pool limited and increase the degree of difficulty for fish passage.

A sediment wedge has deposited upstream of the dam which extends approximately 450-upstream of the upper weir. Gravel bars have reduced the depth of the channel and appear to have added stress to banks which have been riprapped to provide erosion control. The water diversion intake is located 45-ft above the upper weir. The intake is routinely blocked by sediment, requiring periodic removal to maintain capacity.

Structural drawings for the existing dam (USACE, 1983) indicate the stream below the dams was 7-ft below the crest of the lower dam. Presently this stream elevation is approximately an additional 4-ft lower. Thus, the downstream channel has incised at least 4-ft. Some gravel bars are evident below the dams indicating active transport of gravels. The source of these gravels is likely from upstream and transported past the dams. Some sediment could have been derived locally from the stream bank erosion. Through channel downcutting and armoring of gravel bars, the stream bed material would be larger in size and more resistant to erosion than the bank materials comprised of alluvium. This combined with confinement of flows with in the incised channel would be expected to exacerbate the erosion potential.

5.1.2 Alternative 1 – do nothing

Features

The existing structures and operations are unchanged from current practices.

Impacts

- Passage – of adult salmon and adult and juvenile resident fish would remain blocked by the downstream dam.
- Channel stability – sediment deposition would continue to occur upstream with maintenance of the intake required. The downstream channel would be expected to continue to incise through erosion of the bed and banks.
- Debris/ice – existing conditions of debris and ice blockage and damage would not be changed. Continued maintenance of the intake structure would be required.
- Ground water elevations – no change

Pros

- Fish are prevented from passing to upstream reaches, limiting human-bear conflicts and fish-borne nuisances.
- No design, permitting or construction cost

Cons

- Fish are prevented from accessing upstream reaches and habitats.
- Sediment deposition in impoundments and erosion below Elmendorf dam will be expected to continue.

Construction

- No construction. Existing maintenance practices would continue.

Cost

- No cost for design, permitting or construction.
- Current O&M costs would continue.

5.1.3 Alternative 2 – bypass channel

Features

This alternative includes the construction of a small bypass channel around the dam and located on the north bank. The existing topography has steep banks about 13-ft in height on the south side of the creek. The top of the south bank is vegetated with mature trees through a margin approximately 60-ft in width. Beyond the forested margin is the EAFB golf course. Along the south side of the creek (east of the dam) at the upper dam is a large pond and major overhead utility. The north side of the creek has a terrace at mid –

elevation between the downstream creek channel and upper dam. This area is currently used primarily for visitor access to view the stream and fish.

Given the topography and land use, the bypass channel shown in Appendix 7.1 is laid out with a 5-percent channel that extends to switch back on itself near the brood pond, to meet with the creek above the upper dam. The channel would discharge to the scour pool below the lowest dam for best fish attraction. For a 5-percent slope a step-pool channel would be required and can be constructed using rock weirs to control 1-ft drops at 20-ft spacing.

To fit the channel into the available topography, steep banks will likely be required and accommodated using retaining walls or reinforced slopes (e.g. geocell reinforced). Visitor access and safety would require walkways over the channel and safety fencing. Safety fencing can be one component of an anti-poaching/harassment program.

Impacts to the intake building would need to be evaluated. Excavation for construction of the bypass channel may impair or weaken the foundation of the intake building and require strengthening measures. In addition, vehicle access to the intake building may require a structural overpass on the channel.

The inlet to the bypass channel will require an orifice to be cut into the existing sheet pile retaining wall. The inlet to the bypass channel would be located between the upper dam and intake to minimize risk to fish of fallback over the dam or being entrained into the intake. The inlet would have a flow control comprised of flashboards or head gate attached to the existing sheet pile to control or turn off flow entering the channel as needed.

The inlet to the bypass channel will be susceptible to sedimentation, debris and ice blockage and damage. The existing debris deflection log boom can be extended to provide protection to the inlet. On going operation and maintenance of the inlet and bypass channel will be required. Maintenance would require regular checking and cleaning of debris.

<u>Impacts</u>

- Passage - would be improved for adult salmon and adult and juvenile resident fish during the migration period with the ability to manage fish access to upstream reaches.
- Channel stability – negligible change to existing conditions along Ship Creek
- Debris/ice – existing conditions would continue with debris/ice impacts to the inlet.
- Ground water – stream levels will be essentially unchanged. No change to existing ground water – surface water interactions would be expected with the exception of slight increase in infiltration from the bypass channel should it be unlined.

Pros

- Fish would be provided an improved route for upstream passage. The 1-ft jump height proposed would be easily negotiated by adult salmon and adult resident fish. Though the jump height exceeds criteria for juvenile fish, construction of weirs using boulders would provide multiple flow paths across each drop that should enable juvenile resident fish passage.
- The channel outlet located in the scour pool at the base of the dam would provide good fish attraction and ability to locate the entrance to the bypass channel.
- Flow along the channel can be managed by opening and closing the head gate during the migration period allowing active management of fish passage to upstream reaches of Ship Creek.
- Location on the north side of Ship Creek would reduce impacts to mature riparian forest, golf course and large pond along the opposite side. In addition, location would provide good access for operation and maintenance.
- Bypass channel alignment and features could be modified for opportunities for trapping and collection of brood stock or flow routing into the brood pond.
- Improved public viewing.
- Limited modification of the existing dam structure.
- Negligible change to flow and hydraulics of Ship Creek. No change to ground water – surface water interaction; except locally to the bypass channel. No impact to regulatory water surface elevations is anticipated.

Cons

- Bypass channel inlet will be susceptible to sedimentation, debris and icing.
- Channel will require active operation and maintenance.
- Construction of bypass channel will encroach on existing land surfaces and may require additional structural strengthening of intake building, access roads and channel-sheet pile interface.
- Conflict of channel with existing structures and utilities will need to be further analyzed.
- Sediment deposition in impoundments and erosion below Elmendorf dam will be expected to continue.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction can be completed with minimal in stream impacts.
- Existing structures and utilities will need to be accommodated.

Cost

- Conceptual level estimate for construction costs is approximately $550,000.
- Ongoing O&M will be required with relatively moderate costs.
- Cost to accommodate existing utilities and structures is unknown.

5.1.4 Alternative 3 – retrofit fish ladder

Features

Two options present themselves for upgrading or retrofitting fish ladders at the Elmendorf dam as shown in Appendix 7.1. The first option is to extend the existing Alaska Steep Pass (ASP) fishway to discharge into the existing pool below the dams. The second option is to install an entirely new ladder facility along the north side of the creek.

5.1.4.1 Option 1 - extend existing Alaska Steep Pass (ASP) fishway:

The existing fishway is comprised of one segment of Alaska Steep Pass (ASP) fishway at each of the two dams. The upper ASP discharges into the pool between the weirs and would function as intended with removal of debris and sediment. The lower ASP has no water flowing through and the outlet is perched nearly 2-ft above the existing pool below the dams.

The lower ASP could be extended by installation of a turning pool and extension of an additional segment of ASP to discharge into the existing pool. The turning pool could be a prefabricated concrete vault approximately 4- to 6-ft deep, 6-ft long by 8-to 10-ft wide. The vault would be placed as shown in Appendix 7.1 to provide a water surface appropriate for the existing segment of the lower ASP. The new extension of ASP would then turn to flow upstream and discharge in the pool downstream of the dams. Fish would then be able to locate the ASP from the pool, climb the new segment of ASP, rest and turn in the new turning pool, then continue along the existing ASP fishway system.

ASP fishways are impaired by debris and are susceptible to retaining debris. Therefore, active operation and maintenance of the ASP would be required. This option may serve only as a short-term or interim measure. Active management of fish passing to upstream reaches would be possible by closing headgates and turning off flow to the ASP's.

The cost and complexity would be relatively inexpensive in comparison to other options. This would lend itself to a demonstration project approach whereby fish are allowed to access upstream reaches for some period of time. If it is determined that having fish in upper reaches of Ship Creek is not desirable the investment would be fairly small and the vault and ASP could be salvaged for use elsewhere.

Impacts

- Passage – would be improved for adult salmon with management of fish access to upstream reaches possible. The ability of adult resident fish to pass the ASP is not known. Juvenile resident fish would not be able to pass the ASP.
- Channel stability – no change.
- Debris/ice – existing conditions of debris and ice blockage and damage would not be changed. Active O&M would be required.
- Ground water elevations – no change

Pros

- Fish passage would be enabled.

- Management of fish access to upstream reaches would be easily implemented.
- Relatively inexpensive for design, permitting and construction.
- Little in stream impact.

Cons

- May only serve as a short-term or interim measure.
- Susceptible to sediment, debris and ice blockage and damage. Will require active O&M.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction would be relatively simple including removal of some existing riprap, preparation of subgrade, placement of precast concrete vault and installation of new segment of ASP.
- Construction would occur in active Ship Creek flows but would be fairly easy to isolate from the stream.

Cost

- Conceptual level estimate for construction costs is approximately $190,000.
- Ongoing O&M would require daily monitoring and cleaning in response to build up of sediment and debris. Relative O&M costs would be anticipated to be a moderate.

5.1.4.2 Option 2- replace fish way with new weir-pool fish ladder:

Features

This alternative includes installation of a new reinforced concrete fish ladder along the near shore's sheet pile wall. The layout assumes 1-ft drops at each step and will require notching of both weirs to fit the structure and meet profile. The ladder pools will be about 8-ft wide by 10-ft long by 3- to 4-ft deep. The drops will be weirs with the fish exit (upstream end) a vertical slot to limit high flows entering the ladder. The fish way exit would be located between the upstream weir and downstream of the intake to reduce risk of fall back and entrainment, respectively.

At this conceptual level, a weir and pool ladder was selected to maintain water levels during low flows. A vertical slot inlet at the upper end of the ladder would limit high stream flows to capacity of the ladder. More thorough design may indicate that a vertical slot weirs at all drops is feasible and would provide better conditions to accommodate headwater-tailwater fluctuations and passing sediment.

The fish ladder would be susceptible to sediment, debris and ice blockage and damage. The existing log boom can be modified to provide protection to the fish ladder inlet from floating debris. Sedimentation above the dam commonly leaves gravel deposits at an elevation even with the weir crest. Operation of the intake building requires periodic dredging to maintain capacity. This will also impact the fish ladder. A headgate or flash board system can be implemented to control flows in the fish ladder. Removable baffle/flash boards in the upper four weirs could be combined with a gate in the outboard wall to permit flushing sediments from the ladder back to Ship Creek below the upper weir.

Sediment management can be further enhanced by cutting a notch in the weir adjacent to the fish ladder. Flow through the notch can be controlled through use of flashboards or a head gate. With the notch open, flow would flush sediments from the impoundment. Thereby, maintaining capacity to the intake building and fish ladder. With the notch closed, water levels would be maintained at their current levels enabling diversion into the intake building for hatchery supply. Access and safety considerations will need to be developed further for operation of the gates or flash boards.

<u>Impacts</u>

- Passage – would be improved through the fish ladder for adult salmon and resident fish with management of fish access to upstream reaches possible. Passage would be difficult to impassable for resident juvenile fish.
- Channel stability – flow depths and velocities along Ship Creek will be nearly unchanged from existing conditions. Stability of the new fish ladder would be included as a design task.
- Debris/ice – the ladder will be susceptible to debris and ice and will require ongoing O&M.
- Ground water elevations – water levels along Ship Creek will not be changed. Therefore, no change in the surface water - ground water dynamic would be expected.

<u>Pros</u>

- Fish passage would be provided through the fish ladder.
- Operation of the fish ladder would allow active management of fish passage to upstream reaches.
- The fish ladder can be configured to include a fish trap if desired.

<u>Cons</u>

- Fish ladder is a comparatively large construction effort.
- Fish ladder will require a retrofit to the older dam structure. The dam was observed to be in good condition. Additional evaluation of expected service life of the ladder and dam is recommended to establish feasibility.
- Fish ladder is susceptible to debris, sediment and ice blockage and damage.
- Active O&M will be required.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

<u>Construction</u>

- Cutting of sheet pile on the existing dam will be required for installation of the fish ladder and notch. Per the USKH report this appears to be feasible.
- The fish ladder can be constructed of reinforced concrete. Pre-cast units would eliminate raw concrete within the stream corridor and may simplify construction.

<u>Cost</u>

- Conceptual level estimate for construction costs is approximately $890,000.
- Ongoing O&M will be required with relatively moderate to high costs.

5.1.5 Alternative 4 – partial dam removal

Features

The lower weir has jump heights that are currently impassable to fish. The upper weir is moderately difficult to difficult to pass as well. The partial dam removal alternative as shown in Appendix 7.1 was developed to reduce the jump height at both dams to about 3-ft. This height was described in Section 5 as easily passable for wild and hatchery healthy adult Chinook and Coho. This height may be passable for adult resident fish but would be effectively impassable for juvenile resident fish.

Lower weir:

The lower weir currently has a jump height of about 8-ft. Given that Ship Creek downstream of the dams is incised 4-ft or more (from dam drawings), the jump height would be reduced by raising the tail water elevation below the dam. This would be achieved through construction of a roughened channel. At this conceptual phase, the limits of construction and corresponding profile were selected somewhat arbitrarily in an attempt to balance steepness of channel with cost/impact area.

Roughened channel – concept. The roughened channel design approach was first formalized as guidelines by Washington Department of Fish and Wildlife (WDFW). The concept has been implemented over several years for numerous projects. The approach is to design a substrate that provides a desired level of stability. The size of substrate placed includes larger stone to provide this stability. In the size mix is a designed range of sizes to mimic the distribution of sizes found in natural stream substrates. Fine material is included to reduce the risk of low flows going subsurface. In mimicking size distributions of natural stream substrates the assumption is that hyporheic flow (mixing of surface and ground waters), and benthic habitats would emulate naturally occurring conditions. The cross section of the constructed roughened channel is sloped toward the thalweg to concentrate low flows to maintain swimming depths. The thalweg can be meandered along the new channel bed. Boulders and topographic features can be incorporated to provide resting areas. A photograph of an example roughened channel is included on the figure.

Roughened channel – armor layer. Flows tend to winnow away fines from the surface leaving a coarser armor layer along the surface. This condition can be constructed of the larger stone sizes of the substrate mix to reduce the volume of placed fine material entering the stream system. Sediment transported as bed load replaces these materials in a dynamic manner. Ship Creek carries a large bed load which would dynamically deposit and be recruited from this armor layer.

Roughened channel – rock vanes. Given the steepness of the roughened channel slope and harshness of the Ship Creek debris and ice conditions (ice dams, ice flows, frazil/anchor ice, etc.) the elevation of the roughened channel would be fortified with rock vanes constructed of very large boulders placed in an arc (similar to that discussed by MW, 2001). The cross section of the vanes would slope towards the desired thalweg location. The bank portions of the vanes can be sloped to direct flow away from the stream banks to reduce erosion potential. Use of the vanes alone is not recommended as they would act as a large sediment trap, exacerbating erosion downstream until the pools between fill with sediment and begin to pass sediment to downstream reaches.

Upper weir:
The stream above the upper weir has a sediment wedge from the dam extending upstream approximately 450-ft (the upstream end of the bend near the parking lot). The sediment wedge is estimated to be 3.3-ft thick at the dam. Riprap of the banks along the outside of the bend and along a levee between the stream and the pond to the south, no man made grade controls were observed. Above this impoundment is a riffle comprised of cobble material. Based on these observations, it appears that this riffle is geomorphically stable. Extending the slope of this riffle downstream to intercept the upper weir at elevation 93.4-ft. Thus it appears that the weir crest elevation can be notched and lowered 3.3-ft from its existing elevation of 96.7-ft. The stability of the stream in this location must be verified in more detail during later phases with design adjusted if necessary to maintain the desired level of stream stability to protect infrastructure.

If intake elevation requirements allow or are changed, the notch could extend across the full width of the channel. If the existing elevation is required to be maintained for the intake, the notch could extend across only a portion of the weir crest and be controlled by flash boards or a head gate. With the notch open, fish would have about a 3-ft jump height or less to pass the upper weir. Flow would be better able to flush sediments from the impoundment. Thereby, maintaining capacity to the intake building and fish ladder. With the notched closed, water levels would be maintained at their current levels enabling diversion into the intake building for hatchery supply. Access and safety considerations will need to be developed further for operation of the gates or flash boards

Impacts

- Passage – would be improved by reducing jump heights to 3-ft or less, easily passable by healthy wild and hatchery adult Chinook and Coho. This height may be passable for adult resident fish but would be effectively impassable for juvenile resident fish. The upstream weir could be notched providing a moderately-difficult to difficult passage obstacle. Otherwise, management of fish access to upstream reaches is not possible.
- Channel stability – design of the armor rock and rock vanes would account for foreseeable hydraulic and icing conditions. Upstream of the dam an apparently stable slope was identified and extended through the dam impoundment. The upper weir would be cut to this elevation and act as a grade control to upstream reaches. Channel stability should be confirmed during analysis and design at later phases.
- Debris/ice – may more easily pass with less obstruction. If the upper weir notch is controlled, there will be additional obstructions to collect debris and ice. On going O&M should be expected.
- Ground water – minimal impact is anticipated as described in the ground water memo in Appendix 7.5.

Pros

- Adult salmon and possibly adult resident fish would be able to easily jump the two dams and access upstream reaches.
- Provide continuity of stream process
- Reduced risk of debris or ice blockage or damage for the full width notching of the upper weir. (Risk increases if the notch is controlled due to obstructions by flash boards or head gate.)
- Ongoing O&M cost may be less than existing conditions for the full width notching option. However, a monitoring program should be implemented to track the performance of the roughened channel.

Cons

- Management of fish access to upstream reaches would be reduced or impossible.
- Extensive construction in stream.
- Though the design phase would include tasks to address these there will continue to be risk of ice, debris, flood flows eroding the roughened channel materials or stream bank.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction would be extensive in stream.
- An extensive design and permitting effort would be required.
- A comprehensive water diversion and sediment control plan would be critical.

Cost

- Conceptual level estimate for construction costs is approximately $1,400,000.
- Ongoing operation is not anticipated to be necessary. However, a monitoring program should be implemented with maintenance provided as necessary.

5.1.6 Alternative 5 – full dam removal.

Features

The full dam removal as shown in Appendix 7.1 is an expansion on the partial dam removal concept. The channel and weir modifications to the existing dam would require no discrete jumps by fish. The downstream roughened channel described in Alternative 4 would be raised by 1-foot and extended downstream about 20-ft to intercept existing grade. The lower weir would be lowered about 1.0-ft. The upper weir would be lowered 5.5-ft to elevation 91.2-ft. The roughened channel would extend the full distance from 393-ft below the lower weir to 104-ft above the upper weir; for a total length of 547-ft. The elevation at the upstream end of the roughened channel would intercept the slope extension from the apparently stable riffle just upstream of the impoundment. The stability of the stream in this location must be verified in more detail during later phases with design adjusted if necessary to maintain the desired level of stream stability to protect infrastructure.

Impacts

- Passage – would be improved for adult salmon and adult and juvenile resident fish by removing jump obstacles. Management of fish access to upstream reaches is not possible.
- Channel stability – design of the armor rock and rock vanes would account for foreseeable hydraulic and icing conditions. Upstream of the dam an apparently stable slope was identified and extended through the dam impoundment. The roughened channel would extend to meet this slope extension. Channel stability should be confirmed during analysis and design at later phases.
- Debris/ice – may more easily pass with less obstruction.
- Ground water – minimal impact is anticipated as described in the ground water memo in Appendix 7.5.

Pros

- Fish would be able to swim along the roughened channel and access upstream reaches.
- Provide continuity of stream process
- Reduced risk of debris or ice blockage or damage through reduction of obstructions into the stream channel.
- O&M cost is anticipated to be reduced. However, a monitoring program should be implemented to track the performance of the roughened channel.

Cons

- Management of fish access to upstream reaches would not be possible.
- Extensive construction in stream.
- Though the design phase would include tasks to address these there will continue to be risk of ice, debris, flood flows eroding the roughened channel materials or stream bank.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction would be extensive in stream.
- Permitting would be comprehensive.
- A comprehensive water diversion and sediment control plan would be critical.

Cost

- Conceptual level estimate for construction costs is approximately $2,225,000.
- Ongoing operation is not anticipated to be necessary. However, an intensive monitoring program should be implemented with maintenance provided as necessary.

5.2 *Alternatives analysis – Fort Richardson Dam*

5.2.1 Existing conditions

The dam at the Fort Richardson hatchery is located about 3,000-ft downstream from the Glenn Highway. The dam is a concrete slab dam about 5-ft high by 80-ft wide with a steel fish ladder that has filled with debris. A more thorough description of the dam and structural condition is presented in the USKH structural evaluation in Appendix 7.3. The intake to the power plant is not presently in use and has been blocked by an earth fill berm. The dam was originally built to provide cooling water to the power plant. Though presently not in use, the power plant may be reactivated in the future with the associated need for diversion water. Water supply to the hatchery is provided from nearby shallow groundwater wells.

The dam has created an impoundment approximately 340-ft long that has filled with sediment. Based on an average slope from a reach upstream of the impoundment, the extension intercepts the dam about 1-ft below the crest. The sediment wedge includes gravel bars deposited to an elevation higher than the crest of the dam indicating back watering by the dam through the impoundment. The sediment deposition and gravel bar would be anticipated to grow in height to some dynamically stable elevation then migrate laterally across the bed of the stream. This condition makes locating inlets to bypass channels and fish ladders somewhat risky in that flows may be blocked from entering by gravel bars. Active gravel bars are seen downstream of the dam indicating that sediment is transported through the dam impoundment and passed to downstream reaches.

Active bank erosion is seen along the south bank upstream of the dam impoundment. During high flows, the south banks are overtopped at this location. Overland flows are currently prevented from flowing across the meander and re-entering Ship Creek by a utility road embankment and generally hummocky terrain. There is some potential that with time the meander continues to migrate or flood flows cut off the meander. The result could be the meander is cutoff with flows bypassing the meander and dam area.

The existing dam requires about a 5-ft jump from the pool to reach the crest of the dam. This is a moderate effort for healthy adult Chinook and Coho salmon. As described in the USKH structural evaluation this horizontal slab extends for about 40-ft upstream from the crest. Flows would be fast and shallow across this slab adding to the degree of passage difficulty. Thus the degree of difficulty for passage could be assumed to be moderately difficult to difficult, but passable by healthy adult Chinook and Coho salmon. It is unknown if adult resident fish could pass the dam whereas it would be a barrier to juvenile resident fish. Installation of a low sill at the dam crest would increase flow depths across the slab improving swimming conditions.

5.2.2 Alternative 1 – do nothing

Features

The existing structures and operations are unchanged from current practices. The dam is not actively managed or operated.

An existing fish ladder is located at the north end of the dam. This ladder is a small steel structure and is currently filled with debris and unusable. The function of the ladder once cleaned is not known but may provide a passage route for fish. Operation of the ladder would require ongoing O&M to remove debris.

Impacts

- Passage - would be unchanged from existing conditions.
- Channel stability – little change from existing conditions would be anticipated. Gravel bar formation and lateral change in active channel location would be expected to continue upstream. Potential for lateral migration of Ship Creek along reaches upstream and downstream of the dam exists and would be consistent with natural geomorphic dynamics.
- Debris/ice – existing conditions of debris and ice blockage and damage would not be changed.
- Ground water elevations – no change

Pros

- Salmonids are currently unable to reach the Fort Richardson dam by the Elmendorf barrier. However, if salmonids were present, adults would be able to pass this impediment with moderate difficulty.
- No construction or O&M cost
- No change to operation

Cons

- Fish are limited from upstream reaches and habitats.
- Sediment deposition in the impoundments may increase risk of stream bank erosion above the dam.

Construction

- No construction. Existing maintenance practices would continue.

Cost

- No construction cost.

5.2.3 Alternative 2 – bypass channel

Features

Given site topography and access, the bypass channel is proposed along the north shore, as shown in Appendix 7.1 for the most convenience for construction and O&M. The bypass channel discharges into the scour pool for best fish attraction conditions and limit the overall length and cost. The channel alignment is intended to bypass the dam and not impact the existing structure. The inlet to the bypass channel would be located upstream of the concrete slab. A head gate would be required to limit high flow and debris flow impacts. The head gate structure would be incorporated into the existing soil and rock berm which provides protection during floods and ice dam outbursts.

The location and elevation of the active channel and gravel bars above the dam are expected to move dynamically. The bypass channel inlet will be impacted by this movement. It is possible that sediment deposition will prevent flows from entering the bypass channel requiring active maintenance.

Impacts

- Passage - would be improved for adult salmon and adult and juvenile resident fish during the migration period with the ability to manage fish access to upstream reaches.
- Channel stability – negligible change to existing conditions along Ship Creek
- Debris/ice – existing conditions would continue with debris/ice impacts to the inlet.
- Ground water – stream levels will be essentially unchanged. No change to existing ground water – surface water interactions would be expected with the exception of slight increase in infiltration from the bypass channel should it be unlined.

Pros

- Fish would be provided an alternate route for upstream passage. The 1-ft jump height proposed would be easily negotiated by adult salmon and adult resident fish. Though the jump height exceeds criteria for juvenile fish, construction of weirs using boulders would provide multiple flow paths across each drop that should enable juvenile resident fish passage.
- The channel outlet located in the scour pool at the base of the dam would provide good fish attraction and ability to locate the entrance to the bypass channel.
- Flow along the channel can be managed by opening and closing the head gate allowing active management of fish passage to upstream reaches of Ship Creek.
- Location on the north side of Ship Creek would improve convenience of construction and O&M. Location along the outside of the bend is expected to improve the likelihood of the active channel passing the bypass channel inlet.
- Limited modification of the existing dam structure.
- Negligible change to flow and hydraulics of Ship Creek. No change to ground water – surface water interaction; except locally to the bypass channel. No impact to regulatory water surface elevations is anticipated.

Cons

- Bypass channel inlet will be susceptible to sedimentation, debris and icing.
- Channel will require active operation and maintenance.
- Construction of bypass channel will encroach on existing land surfaces and may require additional strengthening of berm.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction can be completed with minimal in stream impacts.

Cost

- Conceptual level estimate for construction costs is approximately $195,000.
- Ongoing O&M will be required with relatively moderate costs.

5.2.4 Alternative 3 – retrofit fish ladder

Features

This alternative includes installation of a new fish ladder along the north shore as shown in Appendix 7.1. The ladder would have features similar to that described for the Elmendorf dam in Section 5.1.4. The ladder would discharge into the pool below the dam for best fish attraction conditions. The inlet into the ladder would be above the concrete slab of the dam. This location would allow easy access for operations and maintenance. However, this location is susceptible to blockage and damage by debris, sediment and ice.

Two options lend themselves to a retrofit to install a new fish ladder. The first option is to notch the existing dam to accommodate a new fish ladder along the north shore. From the structural evaluation, the Fort Richardson dam is not easily modified for retrofitting the fish ladder. The concrete slab structure will require shoring and reinforcing to maintain structural integrity. This option would include a fish ladder similar to that described for the Elmendorf dam. The ladder would be a weir and pool structure with an inlet upstream of the concrete slab, have a 180-degree turning pool to discharge into the pool below the dam.

The second option is to align the ladder to bypass the existing dam structure. This alignment would connect the scour pool below the dam to the channel upstream of the slab. This would require a longer structure and be somewhat redundant to the bypass channel alternative. The greater length would allow a smaller drop at each pool reducing slope but increasing the size of the structure. The disadvantages listed for the bypass channel would apply to this option.

Impacts

- Passage - would be improved through the fish ladder for adult salmon and resident fish with the ability to manage fish access to upstream reaches. Passage would be difficult to impassable for resident juvenile fish.
- Channel stability – negligible change to existing conditions along Ship Creek
- Debris/ice – existing conditions would continue with debris/ice impacts to the inlet.
- Ground water – stream levels will be essentially unchanged. No change to existing ground water – surface water interactions would be expected with the exception of slight increase in infiltration from the bypass channel should it be unlined.

Pros

- Fish would be provided an alternate route for upstream passage.
- The fish ladder outlet located in the scour pool at the base of the dam would provide good fish attraction and ability to locate the entrance to the fish ladder.

- Flow along the ladder can be managed by opening and closing the head gate allowing active management of fish passage to upstream reaches of Ship Creek.
- Location on the north side of Ship Creek would improve convenience of construction and O&M. Location along the outside of the bend is expected to improve the likelihood of the active channel passing the bypass channel inlet.
- For the ladder bypass option, limited modification of the existing dam structure.
- Negligible change to flow and hydraulics of Ship Creek. No change to ground water – surface water interaction; except locally to the bypass channel. No impact to regulatory water surface elevations is anticipated.

<u>Cons</u>

- Existing dam is passable with moderate difficulty. Thus, the need for a fish ladder should be carefully considered.
- Modifications to retrofit a ladder to the existing dam will require design and construction to maintain or improve the integrity of the dam.
- Age and service life of the ladder and dam will be very different.
- Fish ladder inlet and structure will be susceptible to sedimentation, debris and icing.
- Ladder will require active operation and maintenance.
- Construction of ladder will encroach on existing land surfaces and may require additional strengthening of berm.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

<u>Construction</u>

- Construction for the near shore option will be in channel and require shoring and reinforcement of the existing dam structure.
- Construction of the bypass option can be done partially isolated from stream flows.

<u>Cost</u>

- For the ladder retrofit into the existing dam structure conceptual level estimate for construction costs is approximately $540,000.
- For the ladder bypassing the existing dam structure conceptual level estimate for construction costs is approximately $595,000.
- Ongoing O&M will be required with relatively moderate costs. Blockage of the inlet from gravel deposition and debris would be expected to occur periodically adding to the O&M expenses.

5.2.5 Alternative 4 – raise tail water elevation reducing jump height

<u>Features</u>

From the USKH structural evaluation, modification of the dam is not easily completed. Measures to shore and reinforce the structure would be required. Therefore, this alternative includes no modifications to the existing dam. To reduce the jump height, the tail water would be raised through construction of a roughened channel to form a cascade as shown in Appendix 7.1.

As described in the Elmendorf Alternative 4 Section 5.1.5, the roughened channel is a riffle or cascade constructed of rock to raise the tail water elevation. This would reduce the jump height requirement.

The horizontal concrete slab upstream of the crest of the dam has fast shallow flow increasing the difficulty of passage. To ease this obstacle, a low timber or concrete sill could be installed at the crest of the dam to create deeper flow conditions across the slab. The sill would be susceptible to damage by sediment, debris and ice. To reduce this risk, the sill could be chamfered to provide an angled surface to the approach of flow.

Impacts

- Passage – would be improved by reducing jump heights to 3-ft or less, easily passable by healthy wild and hatchery adult Chinook and Coho. This height may be passable for adult resident fish but would be effectively impassable for juvenile resident fish. Management of fish access to upstream reaches is not possible.
- Channel stability – design of the armor rock and rock vanes would account for foreseeable hydraulic and icing conditions.
- Debris/ice – may more easily pass with less obstruction.
- Ground water – The existing dam remains in place with the tail water elevation increased. Therefore, minimal impact is anticipated as described in the ground water memo in Appendix 7.5.

Pros

- Reduced jump height would reduce the degree of difficulty for passage for adult salmon and possibly adult resident fish. The dam would remain a barrier to juvenile resident fish.
- With the exception of the sill option, no modifications would be made to the existing dam structure.
- Provide continuity of stream process
- Reduced risk of debris or ice blockage or damage.
- Little O&M cost

Cons

- Management of fish access to upstream reaches would be reduced or impossible.
- Extensive construction in stream.
- Risk of ice, debris, flood flows eroding the roughened channel materials or stream bank.
- Sediment deposition in impoundments and erosion below dam will be expected to continue.
- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction would be across the full width of Ship Creek. Construction and access for construction would require a comprehensive stream bypass and dewatering system.

Cost

- Conceptual level estimate for construction costs is approximately $450,000.

- Ongoing operation is not anticipated to be necessary. However, a monitoring program should be implemented with maintenance provided as necessary.

5.2.6 Alternative 5 – full dam removal.

Features

This alternative considers full removal of the existing dam from the active channel. This alternative would be an option only after a decision is made to permanently decommission the power plant. Portions of the dam below finished grade would not need to be removed and could remain to provide grade control if needed. Construction of a roughened channel cascade as described for Alternative 4 would provide grade control from below the dam to a location upstream to intercept an extension of an apparently stable upstream riffle. The stability of the stream in this location must be verified in more detail during later phases with design adjusted if necessary to maintain the desired level of stream stability to protect infrastructure. The thalweg can be constructed in a desired location to reduce erosive flows along the north bank. The cross section would be sloped toward the thalweg. A stream bank could be constructed across the former intake inlet

Impacts

- Passage – would be improved for adult salmon and adult and juvenile resident fish by removing jump obstacles. Management of fish access to upstream reaches is not possible.
- Channel stability – design of the armor rock and rock vanes would account for foreseeable hydraulic and icing conditions. Upstream of the dam an apparently stable slope was identified and extended through the dam impoundment. The roughened channel would extend to meet this slope extension. Channel stability should be confirmed during analysis and design at later phases.
- Debris/ice – may more easily pass with less obstruction.
- Ground water – The existing dam would be removed with a lowering of water surface elevation. Some impact to the ground water elevations is predicted as described in the ground water memo in Appendix 7.5.

Pros

- Salmon and resident adult and juvenile fish would be able to swim along the roughened channel and access upstream reaches.
- Provide continuity of stream process
- Reduced risk of debris or ice blockage or damage through reduction of obstructions into the stream channel.
- O&M cost is anticipated to be reduced. However, a monitoring program should be implemented to track the performance of the roughened channel.

Cons

- Management of fish access to upstream reaches would not be possible.
- Extensive construction in stream.
- Though the design phase would include tasks to address these there will continue to be risk of ice, debris, flood flows eroding the roughened channel materials or stream bank.

- Fish access to upstream reaches would increase risk of fish borne nuisances and bear/human conflicts.

Construction

- Construction would be extensive in stream.
- Permitting would be comprehensive.
- A comprehensive water diversion and sediment control plan would be critical.

Cost

- Conceptual level estimate for construction costs is approximately $1,500,000.
- Ongoing operation is not anticipated to be necessary. However, an intensive monitoring program should be implemented with maintenance provided as necessary.

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7 Appendices

7.1 Alternatives figures

7.2 Aquatic physical habitat inventory

7.3 USKH structural investigation

7.4 Shaw sediment contamination investigation, sampling and Analysis

7.5 Shaw groundwater investigation and modeling

7.6 Stream hydrology data

7.7 Stream hydraulics modeling summary output

7.8 Permits

7.9 Estimate of quantities and construction costs

7.10 Landowner correspondence and comments