Yakima River Basin Integrated Water Resource Management Plan

Kachess Reservoir Bull Trout Passage Appraisal Report

Yakima Project, Washington

U.S. Department of the Interior
Bureau of Reclamation
Columbia-Cascades Area Office
Yakima, Washington

State of Washington
Department of Ecology
Office of Columbia River
Yakima, Washington

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Mission Statements

U.S. Department of the Interior
The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and Tribal communities, and supplies the energy to power our future.

The Bureau of Reclamation
The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Washington State Department of Ecology
The mission of the Department of Ecology is to protect, preserve and enhance Washington's environment, and promote the wise management of our air, land and water for the benefit of current and future generations

Contents

1. Introduction

The Kachess Dam was constructed in 1912 at the lower end of two natural lakes — Little Kachess Lake to the north and the bigger Kachess Lake to the south. It is an earth filled structure 115 feet high and 1,400 feet wide at the crest. Above pool elevation of 2,224 feet, the upper and lower water bodies merge into one large reservoir—Kachess Reservoir. The Kachess Reservoir has an active storage capacity of 239,000 acre-feet and is one of five storage reservoirs in Reclamation's Yakima Project in central Washington. It is located in the Cascade Range about 2 miles northwest of Easton, Washington, in the NW¼ of Section 32, T. 22 N, R. 12 E., in the Wenatchee National Forest (Appendix A, Figure 9-1 and Figure 9-2).

When the Kachess Reservoir is drawn down to low levels (below elevation 2,224 feet), the upper Kachess Reservoir and lower Kachess Reservoir are distinguished as they become separated by the river reach between them, referred to as the Narrows.

The U.S. Fish and Wildlife Service (Service) identified designated critical habitat in the five Yakima Project reservoirs, including in Kachess Reservoir, and in the Yakima River basin's mainstem reaches and tributaries. In June 1998, the Service listed the Columbia River Basin's distinct population segment of bull trout as threatened under the Endangered Species Act (ESA).

The Yakima Basin Bull Trout Action Plan Working Group has identified 15 local populations of bull trout in Washington State's Yakima River basin (Reiss et al., 2012). For several years, the Service, the Washington State Department of Fish and Wildlife (WDFW), and the Yakama Nation Fisheries have focused on improving bull trout passage in Box Canyon Creek, an upstream tributary entering upper Kachess Reservoir on the west shore. In 2001, 2003, 2005, these agencies worked together to install a temporary structure that allows adult bull trout to access Box Canyon Creek for spawning. In 2008, the Bureau of Reclamation collaborated with these agencies to prepare the *Box Canyon Creek Fish Passage Improvements Appraisal Report* (Reclamation, 2008), which presented six permanent fish passage solutions for Box Canyon Creek.

In 2012, in an effort to uncover additional water surface supply for agriculture, riverine health, and municipal uses, Reclamation and the Washington State Department of Ecology (Ecology) proposed the Kachess Drought Relief Pumping Plant (KDRPP) to access the Kachess Reservoir's inactive storage. KDRPP is a component of the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan). The operation of the proposed KDRPP would require fish passage improvement and appropriate mitigation of potential adverse effects on bull trout (Reclamation and Ecology, 2012). The KDRPP proposal includes a bull trout enhancement (BTE) package focused on improving acquatic habitat and the abundance and resiliency of bull trout populations in the Yakima River basin

Along with the Box Canyon Creek, the Narrows was also identified as a fish passage concern under the proposed KDRPP.

In 2013, Reclamation and Ecology agreed to conduct an additional appraisal study to address the KDRPP impacts on fish passage at Box Canyon Creek and the Narrows and offer possible solutions. Reclamation and Ecology coordinated this study with the Service, WDFW, National Marine Fisheries Service (NMFS), and the Yakama Nation to form a technical workgroup (TWG), which provided expertise and perspective on additional fish passage options. The TWG held meetings in July 2014, October 2014, November 2014, and February 2015 to provide ideas and review conceptual solutions.

In October 2015, Reclamation, the Yakama Nation, the Service, the U.S. Forest Service (USFS), Ecology, and WDFW signed a Memorandum of Understanding for bull trout recovery in the Yakima River basin. Reclamation and Ecology continue to work with the Yakama Nation and these agencies to evaluate the effects of the proposed KDRPP as a component of the Integrated Plan. (Reclamation and Ecology, 2012).

2. Problems and Needs

Adult bull trout passage into Box Canyon Creek has been a problem for decades, and the Service, WDFW, and the Yakama Nation Fisheries would prefer a permanent solution. Historically, fish passage into Box Canyon Creek has been problematic when the Kachess Reservoir ranges between elevation 2,202.0 (2001) and 2,215.6 feet (2015) in combination with water flow that is too shallow or becomes intermittent in places where the creek flows across the lakebed (Appendix A, Figure 9-3).

In the Integrated Plan, the proposed KDRPP allows for a maximum 80-foot drawdown of Kachess Reservoir below the dam’s existing outlet works (2,192.75 feet) into inactive storage. A fish passage problem occurs at the lower end of the Narrows entering into lower Kachess Reservoir at or below elevation 2,199.5 feet (Appendix A, Figure 9-4) and also at the upper end of the Narrows exiting upper Kachess Reservoir when the water drops below elevation 2,123 feet. In addition, shallow water and insufficient cover throughout the Narrows channel subject the fish to increased predators when the lower Kachess Reservoir drops below elevation 2,123 feet and the flow through the Narrows is minimal (e.g., 34 cfs).

This appraisal report provides a framework of potential mitigation measures for the KDRPP (see proposed locations, Appendix A, Figure 9-5) when used to drawdown the reservoir to access inactive storage in drought years (Appendix A, Figure 9-6, Figure 9-7, and Figure 9-8).

3. Objectives

The objectives of this investigation are to (1) evaluate options to improve upstream fish passage for bull trout into Box Canyon Creek when Kachess Reservoir is drawn down, and (2) evaluate options for upstream passage at the Narrows.

4. Description

Box Canyon Creek and Kachess River

Box Canyon Creek is a tributary of upper Kachess Reservoir approximately 6 miles northwest of the dam and adjacent to the USFS Kachess Campground. Each September, Box Canyon Creek is a primary tributary for bull trout spawning, which provides approximately 1.6 miles of spawning habitat up to Peekaboo Falls.

Kachess River is also a main tributary of upper Kachess Reservoir, approximately 9 miles north-northwest. In late summer and fall, the Kachess River often becomes intermittent approximately one mile upstream of the confluence to the reservoir, making fish passage impossible until late October through early November.

Fish passage into Box Canyon Creek is especially problematic in low water years when the reservoir is drawn down excessively. The alignment of this channel has changed on occasion since the early 1900s. In 1994, Reclamation placed impermeable fabric and sheet pile along the right bank to keep channel stable, and the channel has remained stable in its present location. To facilitate migration during spawning season in low water years, WDFW has built a temporary visqueen-lined, haybale channel four different times in the past 14 years — 2001, 2003, 2005 and 2015 (Appendix B, Figure 9-9 and Figure 9-10). This temporary channel increases flow depth in the channel and prevents flow from going subsurface before reaching the reservoir. Each time this temporary structure is built and removed, it cost between $35,000 and $40,000.

The Narrows

Historically, the Narrows was a 3,100-foot-long river reach separating two historical natural lakes (Appendix B, Figure 9-11 and Figure 9-12). The alignment of this channel does not appear to have changed much since the early 1900s. As part of the proposed KDRPP, the lower Kachess Reservoir could be drawn down to elevation 2,113 feet, which would create a barrier for upstream fish passage at the Narrows depending on date, duration, and depth of drawdown.

Alluvial Fan

It is assumed that the size of the alluvial fan at the confluence of Box Canyon Creek has increased slightly from 2,000 feet long by 3,000 feet wide as described in the appraisal report (Reclamation, 2008). The 2008 appraisal report also assumes that the depth of the alluvial fan has remained relatively stable over the past decade. The depth of aggregation on the alluvial fan is at least 6 feet based on a 1935 pre-dam photograph of exposed tree stumps (Reclamation, 2014) compared with the lack of exposed tree stumps today (Appendix B, Figure 9-13 and Figure 9-14). The Box Canyon Creek streambed elevation at its confluence as it flows onto the alluvial fan may have risen slightly. The maximum rock size in the creek is approximately 5 feet in diameter. The median size is approximately 0.5 to 1.5 foot in diameter (Appendix B, Figure 9-15, Figure 9-16, and Figure 9-17). The alluvial fan is accessible as the reservoir level drops in late summer.

Campground

The USFS Kachess Campground is located on the west shore and south of the confluence of Box Canyon Creek. (See Appendix A, Figure 9-8) A popular summer campground for visitors, its boat ramp becomes partially submerged at normal reservoir pool elevations.

Access

Access to Box Canyon Creek and the Narrows begins at Whittier, Washington (Crystal Springs Exit 62) from I-90 and on to Kachess Lake Road for about 5 miles.

5. Assessment of Existing Conditions and Operations

Geology

Limited field explorations explorations have been performed for Box Canyon and the Narrows previous to this appraisal investigation; the options evaluated are based largely on general geologic knowledge of the area and experience with similar types of materials present in adjacent drainages at Cle Elum and Keechelus dams. However, the *Reservoir and Box Canyon Creek Fish Passage and Sedimentation Trip Report* provides current information on shoreline materials around Kachess Reservoir (Reclamation, 2014).

Geologic explorations of the Narrows area was conducted by Reclamation’s Technical Service Center (Liechty) in November 2015 using electrical resistivity and seismic survey methods. The purpose of this survey was to assess the bedrock depth and the grade control structure that historically and presently maintain the two distinct upper and lower reservoirs at low water surface elevations. Survey results and findings will be published in a Technical Service Center technical memorandum report in 2016.

The drainage areas of the tributary streams discharging into this reach are too small to account for the volume of sediment deposition since the retreat of the alpine glacier approximately 18,000 years ago. Continued sediment deposition from Box Canyon Creek has progressively built the alluvial fan onto the reservoir floor (lakebed). The reservoir floor appears to consist of a relatively extensive glacial outwash plain that separates the upper reservoir from the lower reservoir. Sediment deposition occurs at this change in channel gradient as the creek loses its velocity and no longer transports the same volume of sediment as it does in its other gradient tributary streams. The resulting alluvial fan is a highly unstable depositional environment. It is characterized by extreme pulses of sediment load and unstable channels that moderately infill with sediment and debris while moving frequently across the face of the fan.

The oldest fan deposits are probably inter-fingered at depth with the adjacent outwash terrace materials, while the younger fan deposits likely have moved across the top of the terrace materials, burying the older terrace surface. Hilldale (2014) stated that the Box Canyon Creek alluvial fan "exhibits classic fan formation" and observed that "coarse sediment dominates the near-mouth" and "sand material dominates a large majority of the volume beyond the mouth."

Photographs of the Box Canyon Creek site show bedrock outcrops present along the left bank, downstream of the channel near the confluence of the creek as it flows from the steep valley wall onto the top of the alluvial fan. (Appendix B, Figure 9-10). Because of these documented bedrock outcrops, it is likely that the bedrock becomes shallower when moving up the fan toward the valley wall. The probability of intercepting shallow bedrock significantly increases in the upslope direction. It is likely that bedrock outcrops are also near the surface along the left channel bank and at some undetermined depth beneath the channel floor.

Construction Considerations

Concepts to be studied for the fish passage structures would entail excavation through the alluvial fan deposits and the outwash terraces using standard hydraulic-powered equipment. The alluvial fan materials likely consist of a heterogeneous mix of clay, silt, sand, gravel, cobbles, and boulders. Review of the aerial photographs of the Box Canyon Creek site revealed extensive clear-cut logging in the upstream watershed; several scars from debris flows were noted in the drainage. Debris flows can contribute substantial volumes of sediment to alluvial fans and often transport significant distances.

Materials deposited by debris flows could include very large boulders and monolithic blocks exceeding several feet in diameter. Depending on the size of the excavating equipment used during construction, these large blocks of rock could be difficult to move and could function essentially as bedrock for smaller-sized equipment. Rock excavation methods, such as using pneumatic hoe rams, drilling and blasting, or drilling combined with expansive agents may be required for very large rocks. Elevated sediment levels and debris flows could possibly have impacts on proposed fish structures that may be subject to sediment accumulation.

As an example of similar geology, excavations in the terminal moraine and outwash deposits at Keechelus Dam found many large rock blocks, some approaching 10 feet in diameter and proved very difficult to move even with large heavy equipment. Limited access to Box Canyon

Creek and the Narrows area could also limit the size of equipment that could be used at the site; a provision should be included in the appraisal design for limited amounts of rock excavation to remove large boulders and rock blocks either in the alluvial fan or in the outwash terraces.

Cuts through drained materials should be stable at slopes of about 1.5:1 (H: V) for the granular materials that are expected at the site. Slopes emitting steady seepage may need to be laid back to 2:1or flatter for improved performance. The primary sources of water that could be encountered in excavations for fish passage structures at Box Canyon Creek and the Narrows are assumed to be bank storage from the reservoir. These are found in both the alluvial fan, the outwash terraces, and stream flow from the creek.

The remote location of the site presents an access problem for large drill rigs capable of installing dewatering wells; however, present design concepts envision relatively shallow excavations (15 to 20 feet deep) that tend to preclude the need for extensive dewatering systems. Unless unforeseen groundwater conditions exist at the site, it is likely the dewatering methods, such as use of sump pumps, would prove satisfactory in controlling water in the excavations. Based on information from Cle Elum Dam, it may be prudent to expect significant seepage losses in the constructed fish passage channel. Countermeasures to protect against seepage losses should be considered for the appraisal-level design and could include features such as an impervious membrane liner.

Biology

Kachess Reservoir consists of two adfluvial bull trout populations: one in Box Canyon Creek and the other in upper Kachess River. The lifecycle for Box Canyon Creek and upper Kachess River bull trout populations are shown in Figure 5-1.

Juvenile bull trout reside in their natal tributary until they reach sub-adult size then move into the reservoir until maturity. Adult bull trout migrate from the reservoir into their tributaries to spawn in late summer to early fall. Once they have spawned, the kelts return to the reservoir. Bull trout are capable of spawning annually for several years. Information is absent regarding the movement pattern of adult bull trout in the reservoir. For the purpose of this report, the TWG assumed that bull trout spawners move through the Narrows in June through October.

Prior to spawning, adult bull trout move into Box Canyon Creek in mid-July to mid-August, where the adult spawners reside until ready to spawn in late September to early October. The upper Kachess River spawners reside in the reservoir longer and don’t move into the upper Kachess River until October to early November, which often coincides with a fall freshet event that re-waters an intermittent reach located upstream of the reservoir.

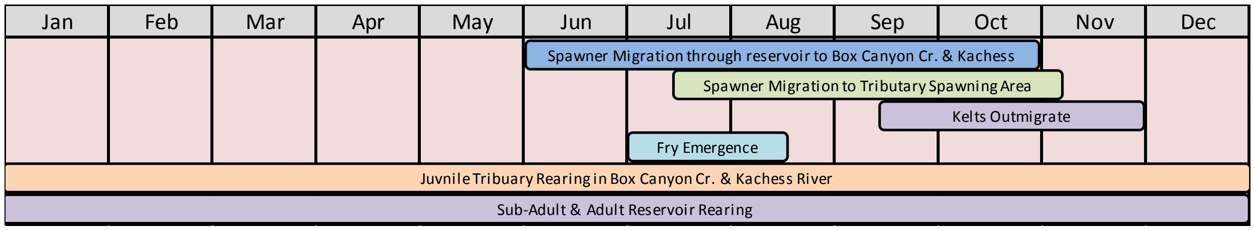


Figure 5-1. Bull trout lifecycle for Kachess River and Box Canyon Creek populations.

Reservoir Operation

Based on historical operations (1994-2015), the Kachess Reservoir pool elevation has ranged from 2,262 feet (full pool) to 2,200 feet (low pool), and the annual median pool elevation ranged from 2,259 feet to 2,225 feet (Appendix C, Figure 9-18). The average monthly pool elevation for the same period was 2,253 feet for July; 2,246 feet for August; 2, 235 feet for September; and 2,223 feet for October. Since 1935, the reservoir pool has been drawn down near the lowest pool elevation of 2,200 feet six times (1979, 1986, 1987, 1993, 1994, and 2001).

Under a Washington State declared drought, the KDRPP could withdraw up to 200,000 acre-feet of water from the Kachess Reservoir. The RiverWare model was used to estimate the number of months during an 83-year period (1926-2008) where the average monthly pool elevation was below 2,199.5 feet. At this pool elevation, fish migrating up from the lower Kachess reservoir cannot pass through the downstream end of the Narrows. During the June through October upmigration period, the Narrows would be impassible a percentage of the time: in June- 13 percent; in July- 23 percent; in August- 29 percent; in September- 37 percent, and in October- 42 percent (Table 1).

Table 1. The number and percent of months that the average monthly lower Kachess Reservoir elevation would be less than 2,199.5 feet when operated under the Integrated Plan, Kachess Drought Relief Pumping Plant scenario (IP2A) for the 1926-2008 period of record. Below this elevation, fish passage from lower Kachess Reservoir into the Narrows becomes impassable for upmigrating fish.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percent of Months Average Water El.<2199.5 feet	**29%**	**29%**	**25%**	**20%**	**19%**	**13%**	**23%**	**29%**	**37%**	**42%**	**37%**	**33%**
Number of Months Water El. <2199.5 feet	**24**	**24**	**21**	**17**	**16**	**11**	**19**	**24**	**31**	**35**	**31**	**27**

6. Hydrologic Information

Hydrology

Modeled average daily flow for Box Canyon Creek for water years 1952-2013 were provided by the U.S. Geological Survey (Mark Mastin, personal communication, 2014). This is a snow-dominated watershed with peak snowmelt occurring in May and June, and summer base flows occurring in September (Figure 6-1).

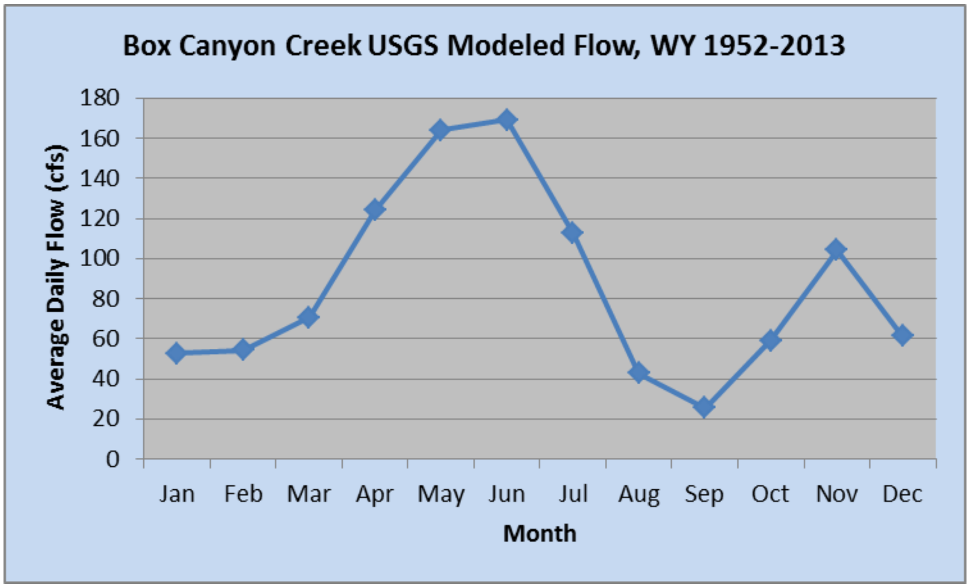


Figure 6-1. Box Canyon Creek USGS Modeled Flow, Water Year 1952 to 2013

Flood flow predictions for Box Canyon Creek are required to determine channel velocities and shear stresses that could occur at the confluence. Velocity and shear stress predictions are needed to design any structural improvements at the site (e.g., rock sizing, armoring, or setting heights of structures).

Since there are no records that measure continuous flow for Box Canyon Creek, flood hydrology was determined by comparing the creek's drainage area (12.7 square miles) with the overall Kachess Reservoir drainage area (63.6 square miles). Box Canyon Creek's drainage area comprises 19.97 percent of the Kachess Reservoir drainage area. This ratio was applied to the inflow data for Kachess Reservoir (KEE gauge station) to determine the Box Canyon Creek daily discharges.

A Log-Pearson Analysis III was used to determine the data for flood frequency based on the period of record, 1920-2007 (Reclamation, 2008). The key results of the Log-Pearson Analysis III are shown in Table 2.

Table 2. Log-Pearson Analysis III Results

Return Period	Discharge (cfs)
2-year	390
5-year	613
10-year	799
25-year	1,086
50-year	1,341
100-year	1,637
200-year	1,979

The calculated maximum daily inflow of 1,528 cubic feet per second (cfs) occurred in Box Canyon Creek in November 1990, which was the highest ever recorded.

Similar flood frequency values have not been calculated for the Narrows, but they could be calculated by using the approach that was done for Box Canyon Creek.

The hydrology used for this report will be verified during the design phase of the project. The flood frequency flows shown above are adequate for planning purposes.

Existing Creek Hydraulics

A Hydrologic Engineering Centers River Analysis System (HEC-RAS) hydraulic analysis of Box Canyon Creek was conducted as part of the *2008 Reclamation Box Canyon Creek Appraisal Report*. The relevant results are summarized in Appendix D, Figure 9-19. Six transects were surveyed from full to low pool along the length of the creek channel then modeled with HEC-RAS to predict the following metrics: flow; minimum bed elevation; water surface elevation; critical water surface elevation; energy gradient elevation; energy gradient slope; mean channel velocity; cross-sectional flow area; wetted channel width and Froude Number. These metrics were calculated for six flows: 5 cfs (minimum bull trout passage); 114 cfs (maximum bull trout flow); 390 cfs (2-year flood occurrence); 799 cfs (10-year flood occurrence); 1,341 cfs (50-year flood occurrence), and 1,637 cfs (100-year flood occurrence).

7. Nine Conceptual Designs Considered

Basic Design Criteria

Design criteria for improved fish passage were derived from the following sources:

- *Anadromous Salmonid Passage Facility Design* (NMFS, 2011)
- *Draft Fishway Guidelines for Washington State* (WDFW, 2000)
- *Design of Road Culverts for Fish Passage* (WDFW, 2003)
- *Swimming Performance of Bull Trout [Salvelinus confluentus]* (Mesa et al., 2003)
- *Critical Swimming Speeds of Wild Bull Trout* (Mesa, et al. 2004)

The following are the design criteria:

- Any proposed Box Canyon Creek fish passage facility needs to operate at a minimum pool elevation 2,224 feet based on a water-surface elevation measurement taken in October 2015 (Edward Young, Reclamation, personnel communication, October 2014). This is the lowest water surface elevation possible and is maintained by the existing grade control (full trees embedded in sediment) at the outlet of upper Kachess Reservoir.
- Any proposed fish passage facility at the Narrows needs to operate from the inflection point, 2,199.5 feet down to 2,110 feet (which represents the maximum inactive pool withdrawal of 200,000 acre-feet).
- Passage conditions through the 3,100-foot channel and at the upstream exit of the Narrows would need to be improved to provide safe fish migration.

Option 1 – Box Canyon: Concrete Open Channel on West Side

Description

Option 1 (Appendix E, Figure 9-20, Figure 9-21, Figure 9-22, Figure 23) would require a 3,000-foot-long concrete open flume on the west shore. The flume would be perched on the rock wall above full pool elevation. A 225-foot-long steeppass ladder would extend from the downstream end of the flume to the reservoir to complete the fish passage route. This steeppass ladder may need an additional 20 or more resting pools to meet the design criteria. A diversion structure, infiltration gallery, headgate, and high-density polyethylene (HDPE) pipe for the water supply would be located where the creek leaves the canyon immediately upstream of the full pool elevation. The infiltration gallery will feed the water into the pipe and flume. The filter will keep out gravel and debris. Approximately 8 to10 small resting pools may be required from inside the flume.

Pros

- Sediment control is the primary advantage of this option, which should reduce overall operation and maintenance (O&M) costs. Closure of the headgate during high-flow events, for example, would minimize the amount of sediment and bedload material that would be recruited into the flume and steeppass structures.

Cons

- The U.S. Forest Service may have concerns with this option, as use of the trail on the bluff adjacent to their campground would present visual impacts and safety issues.
- The TWG had concerns over the extensive length of the steeppass fishway (225 feet) and number of required resting pools based on NMFS criteria.

Option 1 Conclusion: In November 2014, TWG expressed some design concerns and recommended that Jeff Brown (NMFS) and Bruce Heiner (WDFW) review this design. In February 2016, the TWG agreed to keep Option 1 for future consideration. However, due to the high cost estimate ($2,189,388.20) and the Cons listed above, the TWG favors Option 2 (below) over this option.

Option 2 – Box Canyon: Roughened Channel

Description

Option 2 (Appendix E, Figure 9-24, Figure 9-25, Figure 9-26, and Figure 9-27) would consist of an roughened channel up to 2,580 feet-long and constructed within the existing creek channel. The roughened channel length is based on the distance from where the creek exits the canyon to the lowest possible water surface elevation of 2,224 feet. The roughened channel would be designed for high-spring to low-summer flow conditions similar to the Bruton roughened channel on lower Taneum Creek (Appendix, E, Figure 9-25). Underneath the roughened channel an impervious barrier would prevent loss creek flow across the reservoir lakebed.

Pros

- This option uses the existing creek channel, which has proven stable since the mid-1990s and provides a more natural passage solution. Compared to Options 1 Box Canyon: Concrete Open Channel on West Side) and 3 (Box Canyon: Water Pumped from Upper Reservoir), Option 2 is likely to need less O&M and would be less expensive to construct.

Cons

- There is potential for channel avulsion, which would likely require sediment and bedload management.
- The roughened channel may wash out in a flood event.

Option 2 Conclusion: In November 2014, TWG expressed interest in this option and considered it the most favorable of the three Box Canyon options. In February 2016, TWG supported Option 2 as the preferred option for fish passage improvements to Box Canyon Creek.

Option 3 – Box Canyon: Water Pumped from Upper Reservoir

Description

Option 3 (Appendix E, Figure 9-28) would consist of (1) a permanent pump station on the north side of the USFS Kachess campground or (2) a semi-permanent pump barge located in the reservoir near the campground. Either pump type would supply water up to 20 cfs. The discharge pipe would follow the shortest distance (approximately 1,800 feet) to where Box Canyon Creek leaves the canyon and begins to flow onto the reservoir lakebed. Water would exit the discharge pipe through a transition diffuser box before entering the creek. If electricity is unavailable in this area, a large generator could be placed on the pump barge to provide power.

Pros

- Uses the existing creek channel and in principle would require little, if any, channel modification.
- Pumping supplemental water into the creek would not be needed every year, and only when the creek becomes intermittent to provide passage for spawning adults and kelts.

Cons

- The cost to bring electrical power on site via transmission lines could be expensive, and the use of a diesel powerplant as the electrical source has air quality and noise issues.
- There would be an associated power cost to operate the pumps.
- The pump intake would require a fish screen to meet NMFS criteria.
- There could be insurmountable recreational and social issues given that the pump station would be located within the boundaries of the USFS Kachess campground.
- Water supply would be a mixed water source instead of solely Box Canyon Creek water causing a possible fish attraction issue.

Option 3 Conclusion: The TWG met November 2014 and suggested that additional information be gathered on the Con issues listed above before making a final decision on this option. In February 2016, TWG considered Option 3 non-viable because of the environmental and power costs cited.

Option 4 – The Narrows: Lower to Upper Reservoir Passage - Gravity Flow from Mineral Creek

Description

Option 4 (Appendix E, Figure 9-29 would divert 25 cfs of water from Mineral Creek, a tributary to upper Kachess River, through a 3-mile-long pipeline to a 4,000-foot-long flume located on the east shore above the reservoir's full pool elevation. Mineral Creek water would serve as a source of gravity-flow water for the flume. The upstream end of the flume extends into upper Kachess Reservoir above the Narrows. At the downstream end of the flume, 275-foot-long steeppass fishway would extend into lower Kachess Reservoir to complete the fish passage route. This design is similar to Option 1 for Box Canyon Creek.

Pros

- Provides a gravity water source for the flume.

Cons

- The upper Kachess River has a stream reach upstream of the reservoir that chronically becomes intermittent in late summer. Diverting Mineral Creek water would further exacerbate the ability of bull trout to migrating through this reach to access their headwater spawning area in most years.
- Environmental issues are associated with the construction of a 3-mile-long pipeline through the Alpine Lakes Wilderness Area.
- A potential fish attraction issue could arise, especially for the Box Canyon Creek bull trout population, when using Mineral Creek as the water source for the open flume.
- Long-term O&M of the facility could prove challenging given it would be sited on a steep slope prone to avalanches and falling trees.

Option 4 Conclusion: In November 2014, TWG suggested Option 4 not be carried forward, because the diversion of Mineral Creek would exacerbate the low-flow condition that already exists in the upper Kachess River. The use of Mineral Creek as the sole water source would create a fish attraction issue for bull trout migrating to Box Canyon Creek and potentially to the upper Kachess River.

Option 5 – The Narrows: Lower to Upper Reservoir Passage - Electrical Pump

Description

Option 5 (Appendix E, Figure 9-30) would be the same as Option 4, but instead of diverting Mineral Creek water to service the flume, a pump station would be installed, and water from upper Kachess Reservoir would be used. The pump station would be located on the east shore of upper Kachess Reservoir. An alternative for the pump station could be a pump barge placed in the reservoir. As there is no power source in the area, a diesel powerplant could provide a power source.

Pros

- Upper Kachess Reservoir would provide water to the flume, which would eliminate the dewatering of the upper Kachess River and the fish attraction issue identified in Option 4.

Cons

- Uncertainty on the availability of power.
- The U.S. Forest Service may have concerns, as the flume is located in sight of the campground and would present a visual impact and potential safety issues.
- The TWG had concerns over the extensive length of the steeppass fishway and number of required resting pools based on NMFS criteria.

> **Option 5 Conclusion:** In November 2014, TWG suggested Option 5 not be carried forward based on the issues identified with installation and operation of a pumping plant, concerns over the extensive length of the steeppass fishway, and number of required resting pools needed based on NMFS criteria.

Option 6 – The Narrows: Lower to Upper Reservoir Passage - Natural Channel

Description

Option 6 (Appendix E, Figure 9-31) would consist of a diversion weir and control gate located upstream of Box Canyon Creek near the canyon mouth. It would divert 25 cfs of flow from Box Canyon Creek into a 2,800-foot-long, natural-designed open channel and flow into lower Kachess Reservoir. The natural bypass channel would go through the boundary of the USFS Kachess campground.

Pros

- Provides a gravity-flow water source that flows through a natural-designed channel into lower Kachess Reservoir for bull trout spawners.

Cons

- Diverts water from Box Canyon Creek, which chronically suffers from low-flow to intermittent conditions in the late summer, especially in drought years. Diverting more water would further exacerbate the problem, as Box Canyon Creek flow is often less than 25 cfs.

- Using Box Canyon Creek as a water source for the natural-designed channel would create a potential fish attraction issue, especially for the upper Kachess River bull trout population.
- Migrating bull trout and other fish species would be subjected to increased risk from predators (human and natural) as they swim through natural-designed channel.
- Locating an acceptable right-of-way for the channel through the existing campground would be an issue.

Option 6 Conclusion: The TWG met November 2014 and suggested Option 6 not be carried forward based primarily on the diversion of water from Box Canyon Creek and the fish attraction issue for the upper Kachess River bull trout population. In addition, Box Canyon Creek water would have to be shared with the fish passage Option 1 (Box Canyon: Concrete Open Channel on West Side), and this would likely be a problem when the creek flows are low.

Option 7 – The Narrows: Full Span Concrete Weir and Fishways

Description

In Option 7 (Appendix E, Figure 9-32 and 9-33) the flume and the steeppass fishway would be similar to Option 5 (The Narrows: Lower to Upper Reservoir Passage - Electrical Pump), but the flume would be 2,000 feet shorter. The gravity flow (25 cfs) from upper Kachess Reservoir would be diverted from the concrete weir into the flume. The span of the concrete weir would be approximately 15 to 20 feet high and 700 feet long.

Pros

- The upper Kachess Reservoir would provide a gravity water source for the flume.
- The flume would be approximately 2,000 feet shorter than the flume for Options 4 (The Narrow: Gravity Flow from Mineral Creek) and Option 5 (The Narrows: Lower to Upper Reservoir Passage - Electrical Pump).
- The weir could function as grade control for upper Kachess Reservoir and potentially lessen the passage issue on Box Canyon Creek by maintaining a high water-surface elevation.

Cons

- This option would require the construction of a large weir across the Narrows.
- There is uncertainty concerning the geologic conditions in the Narrows area, specifically, concerning the depth-to-bedrock along the axis of where the weir would be located. As the depth-to-bedrock increases, the cost to construct the weir escalates.
- A weir extending across the width of the Narrows presents public safety concerns.

- Long-term O&M could may be expensive as it would be sited on a steep slope that could be prone to avalanches and falling trees.

> **Option 7 Conclusion:** The TWG met November 2014 and considered Option 7 as viable. The TWG believed that construction of a grade-control structure for KDRPP would be needed to protect the existing upper Kachess Reservoir pool elevation to prevent further worsening of passage conditions in Box Canyon Creek.
>
> After observation in 2015 of the grade control (full trees embedded in sediment) for the upper Kachess Reservoir, the TWG concluded that under proposed KDRPP operations, the grade control would remain stable. In February 2016, the TWG suggested dropping Option 7.

Option 8 – The Narrows: Fish Trap-and-Haul System

Description

Option 8 (Appendix E, Figure 9-34) would consist of a floating surface collector (FSC) similar to that used on Baker Lake by Puget Sound Power and other locations in the northwest. The collector would be much smaller. Key components of a FSC are the floating barge, a collection box, an incline dewatering screen, and pumps to provide attraction flows. An additional system would be needed to transport fish from the FSC to release them into upper Kachess Reservoir. A power source would be needed to operate the FSC.

A variation of Option 8 would provide the attraction flow with gravity-fed water piped from the Narrows to the FSC. This would eliminate the need for pumps.

Pros

- Used only when needed (e.g., KDRPP is used to access the inactive pool in a drought year.
- Effective over any reservoir pool elevation.
- Possible to incorporate a Whooshh™ fish transport tube with the FSC to streamline moving fish to the upper reservoir.

Cons

- Option 8 may require an onsite power source (e.g., grid power or a generator). As an alternative, it may be possible to use gravity flow from water passing through the Narrows.
- When the structure is not in use, it would need to be transported to off-site storage location.
- The fish must be physically handled, transported, and released upstream of the Narrows.
- Floating surface collectors are typically O&M intensive.
- The willingness of adult bull trout to move into a FSC in not proven.

Option 8 Conclusion: The TWG met November 2014 and considered Option 8 as viable because the FSC would operate over any range in pool elevation. On February 2016, the TWG continues to support Option 8, but expressed reservations on the viability of the FSC design because of the observed reluctance of adult bull trout to use the north fork Tieton River weir trap.

Option 9 – The Narrows: Full-Reach Grade Control Structures

Description

Option 9 (Appendix E, Figure 9-35) would consist of a roughened channel extending from upper Kachess Reservoir, through the Narrows, and downstream into lower Kachess Reservoir. There is a 12 to 48 percent channel gradient (Figure 7-1 below) through the Narrows (north profile) between the two reservoirs, requiring installation of several grade-control structures in the roughened channel. These structures would create a step-pool, weir-type passage to provide fish sufficient resting pools with adequate water depth. This would allow easy passage over each successive step-pool.

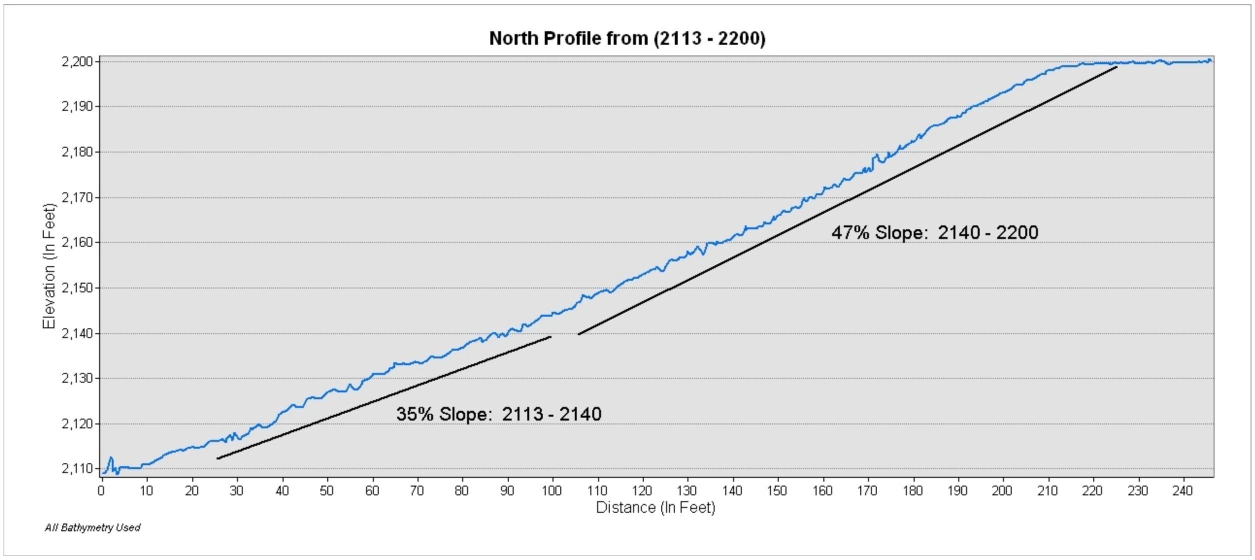
Pros

- A passive fish passage system.
- Electricity would not be required.

Cons

- Geologic conditions are unknown and need investigation.
- Long-term stability and O&M costs would need careful consideration.
- Unless it is a permanent structure with a well-engineered design (which may cost more), the channel and grade controls may wash out in a flood.
- The channel slope is greater than NMFS fish passage criteria allowable for a roughened channel design and for use of a steeppass ladder.
- Construction of a roughened channel or a steeppass ladder would require drawing down the reservoir the potential elevation 2,110 feet, which would have many project operations considerations.

Option 9 Conclusion: The TWG met November 2014 and supported Option 9 as a viable alternative. In February 2016, TWG suggested Option 9 not be carried forward. The channel slope from the Narrows' inflection point downstream into the upper end of the lower Kachess Reservoir is upwards of 48 percent. This gradient is considerably greater than NMFS' maximum design criteria of 6 percent for a roughened channel and 28 percent for a steeppass fishway (*NMFS Anadromous Salmonid Passage Facility Design*, February 2008).



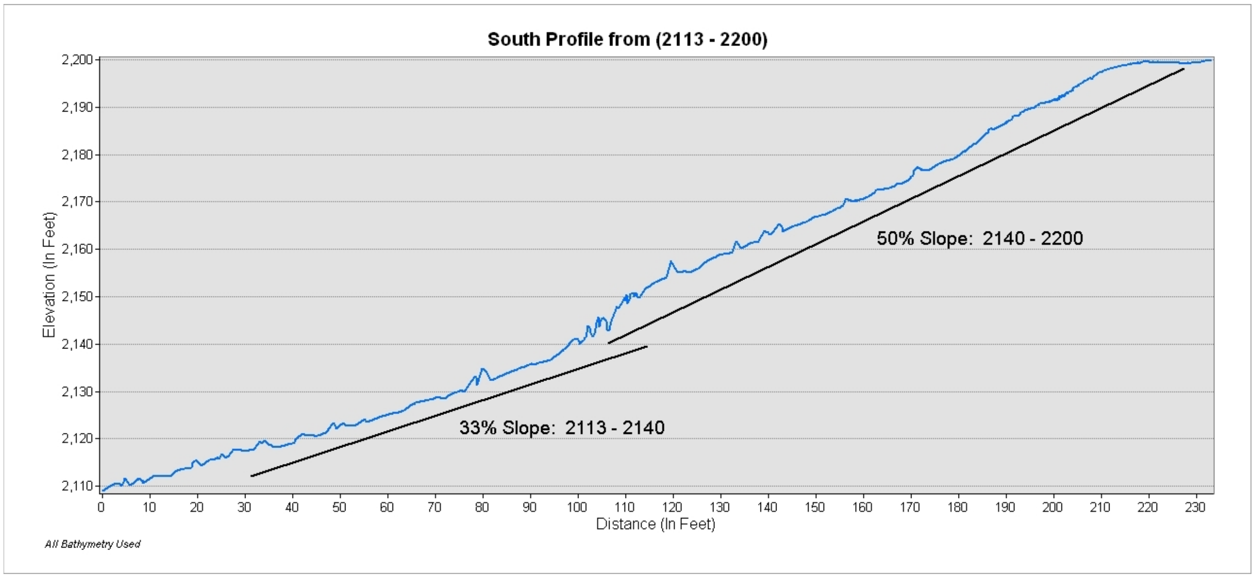


Figure 7-1. The north and south gradients following the thalweg routes from the downstream end of the Narrows to the upper end of lower Kachess Reservoir.

Conclusions and Recommendations

1. Reclamation and Ecology will advance Option 2 (Box Canyon: Roughened Channel), as supported by the TWG, for further consideration. Detailed drawings and cost estimates will be prepared. Option 2 includes construction of a roughened channel within the footprint of the existing channel that flows north along the rock wall on the west shore and into Kachess Reservoir. Option 2 would eliminate the need for the perched flume and steeppass ladder. Option 2 is a more natural solution and has the benefit of creating fish habitat. Furthermore, the existing channel has remained stable since 1994.

2. Reclamation and Ecology have confirmed, in consultation with the TWG, that the existing grade control at the Narrows must be maintained to prevent further damage to Box Canyon

Creek fish passage. Note: field observations in October 2015 suggested that the grade control for upper Kachess Reservoir is stable and is unlikely to be compromised if exposed to a fall freshet event. The grade control consists of a log jam embedded in fine sediment, which appears likely to remain stable after a high-water event.

3. Reclamation and Ecology will continue to gather information for Option 8 (The Narrows: Fish Trap-and-Haul System) for passage at the Narrows, while recognizing TWG's concern about the design of the floating surface collector facility.
4. Reclamation and Ecology will not advance Option 9 (The Narrows: Full Reach Grade Control Structures) as currently proposed, as it does not meet NMFS's fish passage criteria. Reclamation, Ecology, and consultants are investigating an alternate configuration (see No. 8 below) that would increase the channel length, decrease the channel gradient, and extend the channel along the eastern shore, which would meet NMFS's fish passage criteria.
5. Reclamation and Ecology would add grade-control structures and large woody debris to the Narrows channel to improve bull trout passage conditions as recommended by the Washington State Department of Fish and Wildlife, the Service, and the Yakama Nation.
6. Reclamation and Ecology will consider a no action option for Box Canyon Creek and continue to address the passage issue by installing the temporary flume similar those built in 2001, 2003, 2005, and 2015. The infrequent need and inexpensive cost ($35,000 to $40,000) to install and remove the flume, compared to the cost of a permanent facility, may warrant further consideration. A similar conclusion was expressed in Reclamation's previous *Box Canyon Creek Fish Passage Improvements, Appraisal Report* (Reclamation, 2008). A summary of the estimated cost for each option is shown in Table 2.
7. Grade control is of critical importance at the upstream end of the Narrows. The TWG highly recommended a geological investigation throughout the Narrows area to delineate depth-to-bedrock and soil types. The Technical Service Center (Liechty[1]) completed the survey in November 2015 and the results will be available in 2016.
8. As mitigation for the maximum 80-foot drawdown into the inactive pool, Reclamation, Ecology, the Roza Irrigation District (Roza), and the Kittitas Reclamation District (KRD) are considering a conceptual design for a volitional fish passage from the Narrows to lower Kachess Reservoir. The roughened channel concept would be approximately 1,500 feet long at 6 percent grade and would direct the water in the Narrows along the east shore of the reservoir. See Figure 7-2 for conceptual route.

[1] Liechty Report Technical memorandum 85-833000-2016-1: Geophysical Surveys, Seismic refraction, Little Kachess Narrows top of bedrock, Little Kachess Reservoir, Washington.

Table 2. Summary of Estimated Costs for Box Canyon and Narrows Options

Option	Title	Cost
1	Box Canyon: Concrete Open Channel on West Side	$2,189,388.20
2	Box Canyon: Roughened Channel	$1,912,197.00
3	Box: Canyon: Water Pumped from Upper Reservoir	Rejected
4	The Narrows: Lower to Upper Reservoir Passage - Gravity Flow from Mineral Creek	Rejected
5	The Narrows: Lower to Upper Reservoir Passage - Electrical Pump	Rejected
6	The Narrows: Lower to Upper Reservoir Passage - Natural Channel	Rejected
7	The Narrows: Full Span Concrete Weir and Fishways	Rejected
8	The Narrows: Fish Trap-and-Haul System	To be determined
9	The Narrows: Full-Reach Grade Control Structures	To be determined

Figure 7-2. Roughened channel at the Narrows along the east shoreline of lower Kachess Reservoir under proposed KDRPP.

Next Steps

Reclamation and Ecology will continue to evaluate potential mitigation options discussed above for impacts from KDRPP. As the KDRPP is refined and an additional alternative of a floating pumping plant is evaluated, Reclamation and Ecology will continue to consult with the TWG to identify appropriate mitigation at Box Canyon Creek and the Narrows.

8. References

Citation in Document	
Mesa et al., 2003	Mesa, Matthew G., Weiland, Lisa K., Zydlewski, Gayle B., 2003. *Swimming Performance of Bull Trout* (*salvelinus confluentus*). U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (FWS). USGS, Western Fisheries Research Center, Columbia River Research Laboratory and FWS, Abernathy Fish Technology Center. Cook, Washington and Longview, Washington.
Mesa, et al. 2004	Mesa, Matthew G., Weiland, Lisa K., Zydlewski, Gayle B., 2004. *Critical Swimming Speeds of Wild Bull Trout*. U.S. Geological Survey (USGS) and U.S. Fish and Wildlife Service (FWS). USGS, Western Fisheries Research Center, Columbia River Research Laboratory and FWS, Abernathy Fish Technology Center. Cook, Washington and Longview, Washington.
NMFS, 2011	*Anadromous Salmonid Passage Facility Design*. National Marine Fisheries Service, Northwest Region, Portland, Oregon.
Reclamation, 2008	Bureau of Reclamation, Pacific Northwest Region PN3400 2008. *Box Canyon Creek Fish Passage Improvements, Appraisal Report*. PNR Design Group. Boise, Idaho.
Reclamation and Ecology, 2012	*Yakima River Basin Integrated Water Resource Management Plan, Framework for Implementation Report.* Contract No. 08CA10677A ID/IQ. Prepared by HDR Engineering, Anchor QEA, ECONorthwest, Natural Resource Economics & ESA
Reclamation, 2012	Bureau of Reclamation. 2012. *Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement*. Columbia-Cascades Area Office. Yakima, Washington
Reclamation, 2014	*Kachess Reservoir and Box Canyon Creek Fish Passage and Sedimentation: Trip Report of Site Visit Oct. 14-15, 2014*. Technical Service Center, Denver, Colorado. Sedimentation and River Hydraulics Group, 85-824000
Reiss et al., 2012	Reiss, Yuki K., Jeff Thomas, Eric Anderson and Jim Cummins (2012). *Yakima Bull Trout Action Plan*. Yakima Basin Fish and Wildlife Recovery Board, WDFW and the U.S. Fish and Wildlife Service.
WDFW, 2003	*Design of Road Culverts for Fish Passage*. Washington State Department of Fish and Wildlife, Olympia, Washington.
WDFW, 2000	Bates, Ken, 2000. *Fishway Guidelines For Washington State*. Washington State Department of Fisheries. Olympia, Washington.

9. Appendices A-F

Appendix A – Location Maps

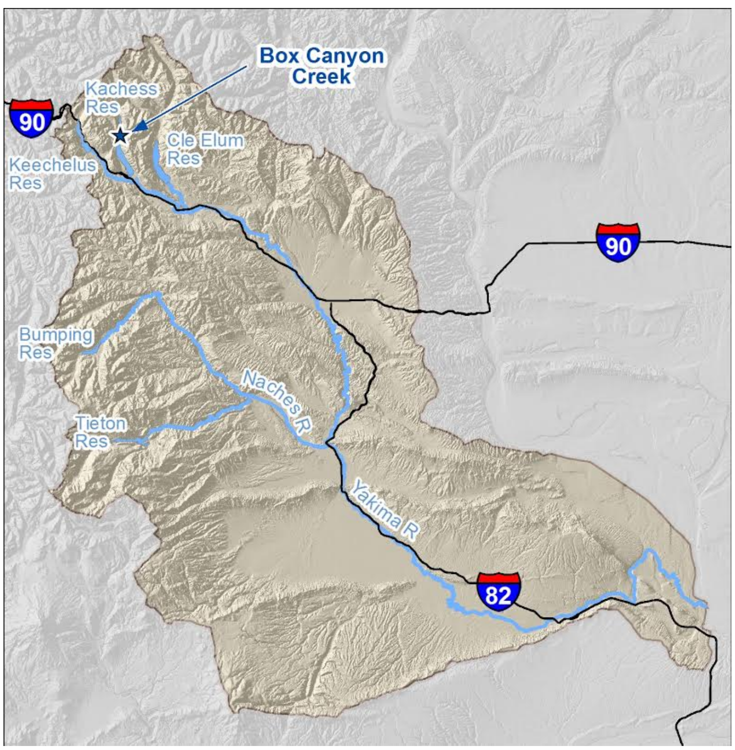


Figure 9-1. The Kachess Reservoir is located off I-90 at the top of the Yakima River basin in central Washington State about 2 miles northwest of Easton. See maps above and below

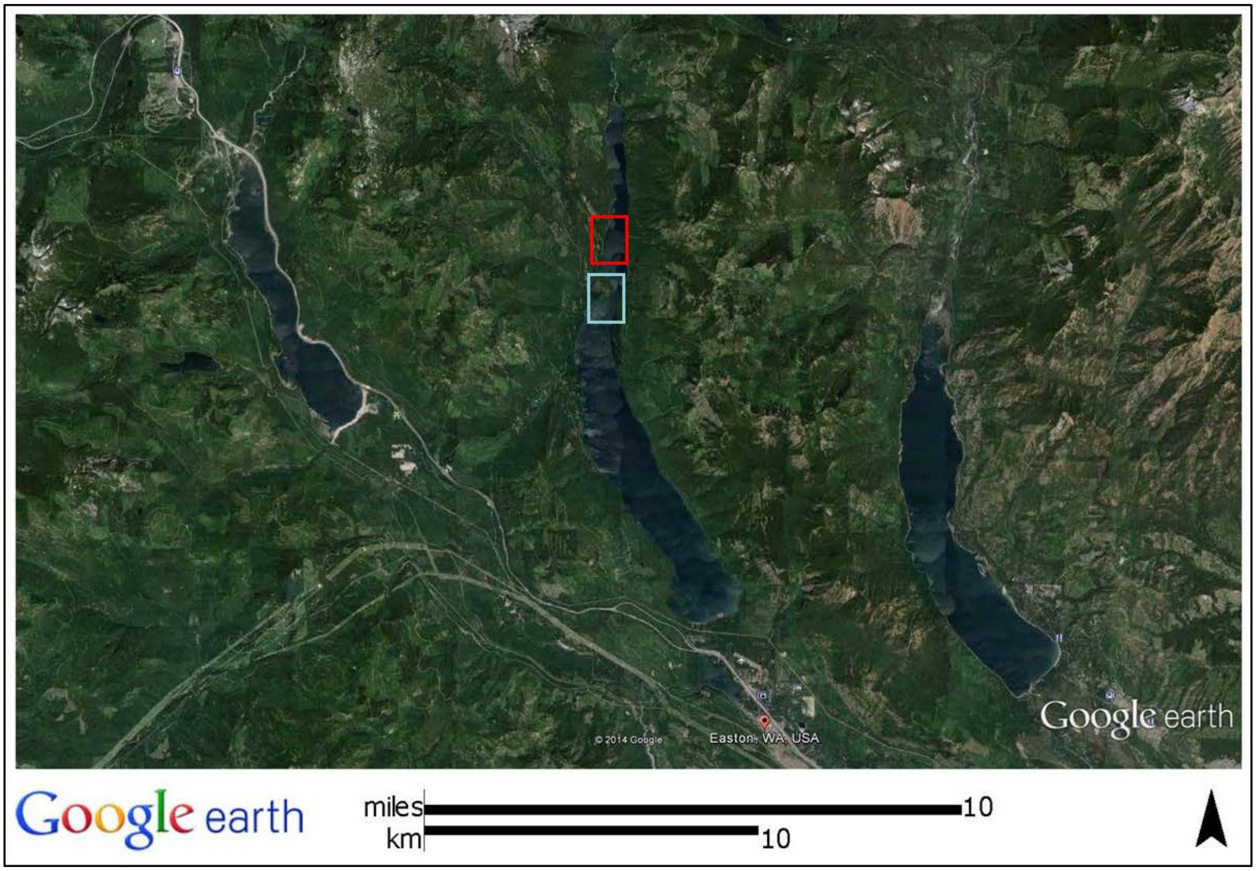


Figure 9-2. Aerial photograph of Keechelus, Kachess, and Cle Elum reservoirs in the Cascade Range, listed in order from west to east (left to right). Kachess Reservoir is the middle nearest to Easton, Washington. The red square indicates the location of the inset map of Box Creek Canyon shown in Figure 9-3. Blue square indicates the inset location of the Narrows shown in Figure 9-4.

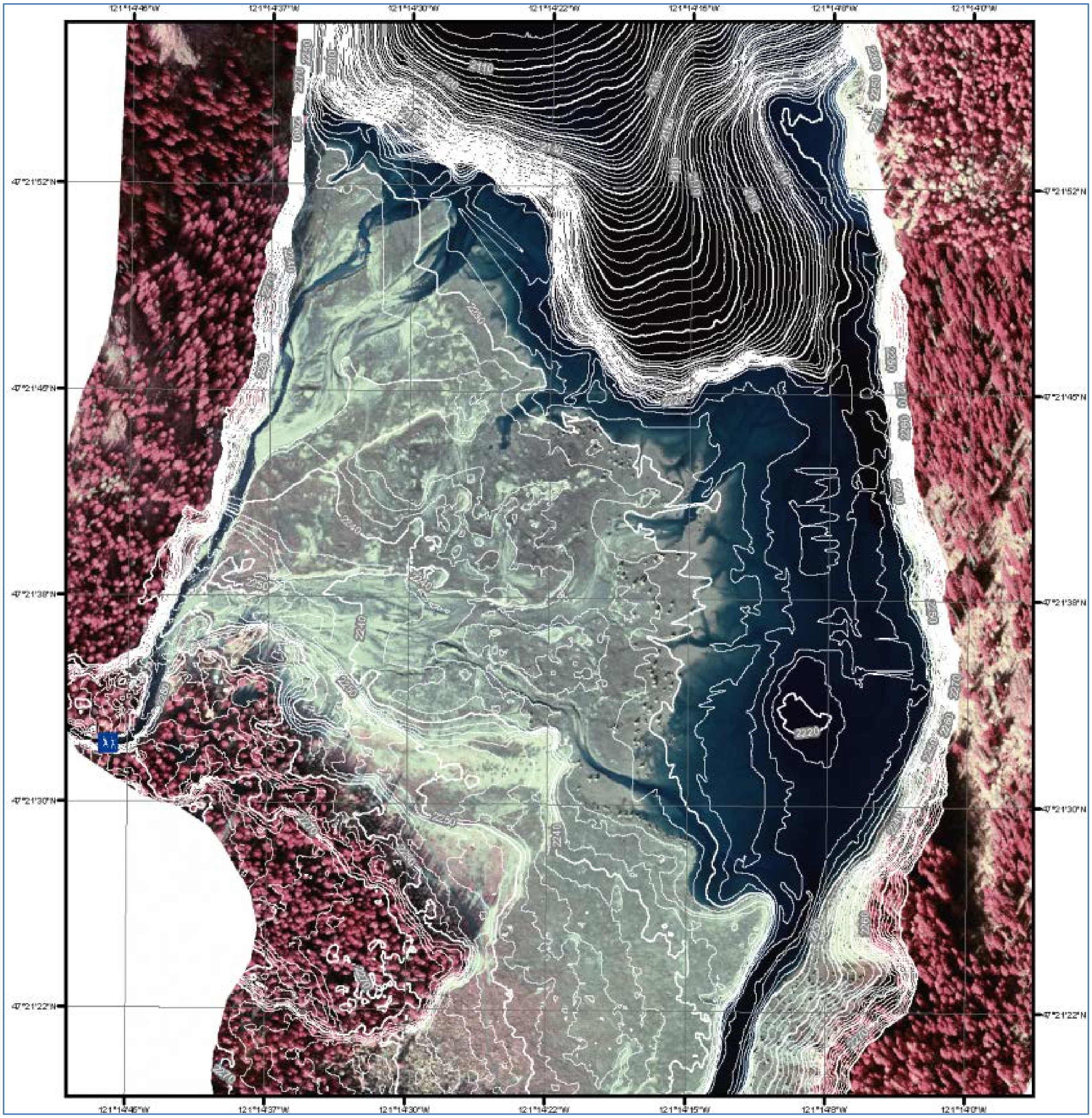


Figure 9-3. Inset view of Box Canyon Creek on the west side of the reservoir (red square on Figure 9-2) and the Narrows area (bottom right of the photograph) between lower Kachess Reservoir to the south and upper Kachess Reservoir (to the north). Water surface El. 2,230 feet (approx.). Drawing Date: November 2000

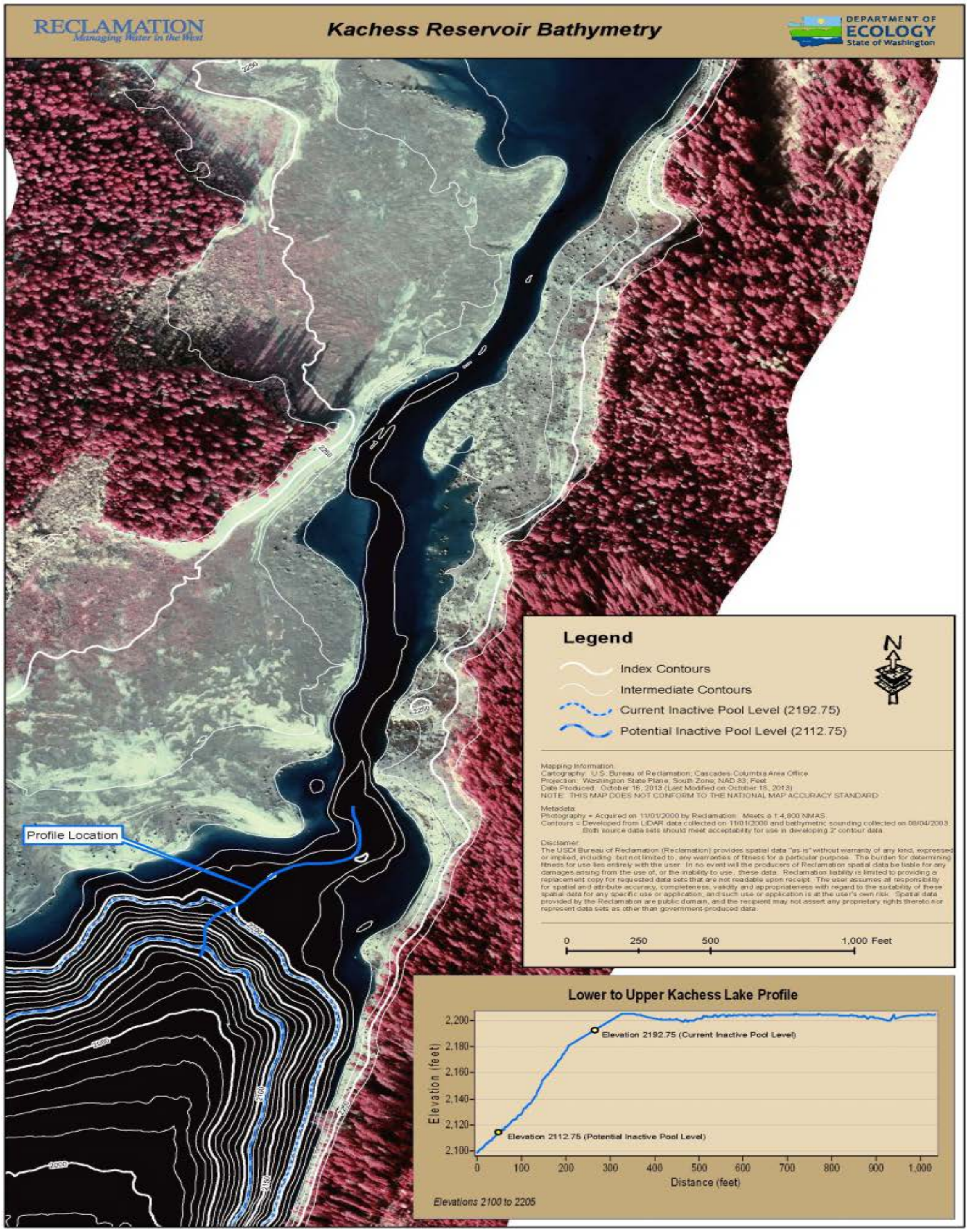


Figure 9-4. Map of the Narrows area between lower and upper reservoirs. Location is indicated with the blue box inFigure 9-2. The inset graph shows the lakebed profile from upper reservoir into the Narrows. Box Canyon Creek is out of the photograph to the north. Approximate water surface El. 2,230. Photo Date: November 2000.

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Figure 9-5. Proposed locations for the Kachess Drought Relief Pumping Plant (KDRPP).

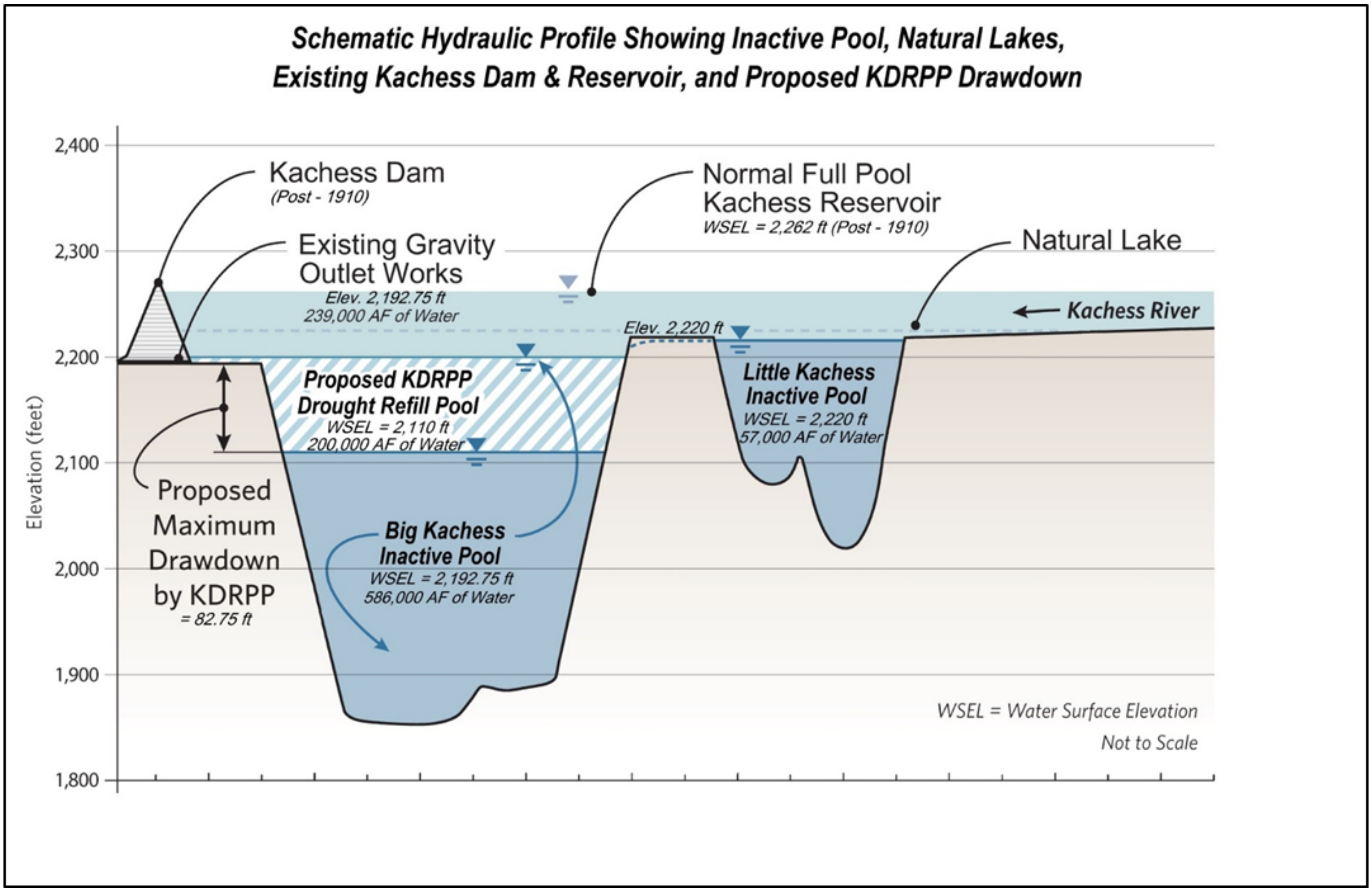

Figure 9-6. Schematic hydraulic profile showing the inactive pool, natural lakes, existing Kachess Dam and Reservoir, and the proposed Kachess Drought Relief Power Plant (KDRPP) drawdown.

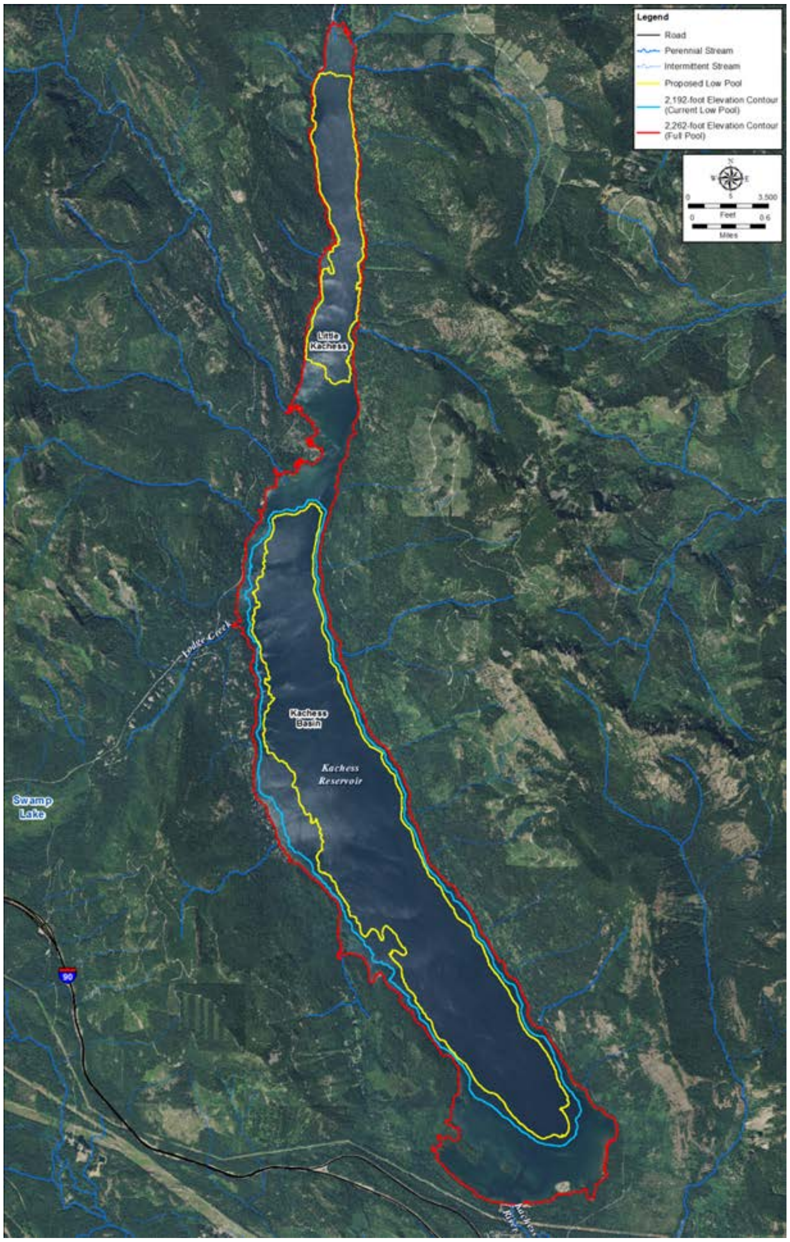

Figure 9-7. Reservoir elevations for full pool (red - El. 2,262 feet), current low pool (blue – El. 2,292.75 feet), and the proposed low pool (yellow - El. 2,110 feet).

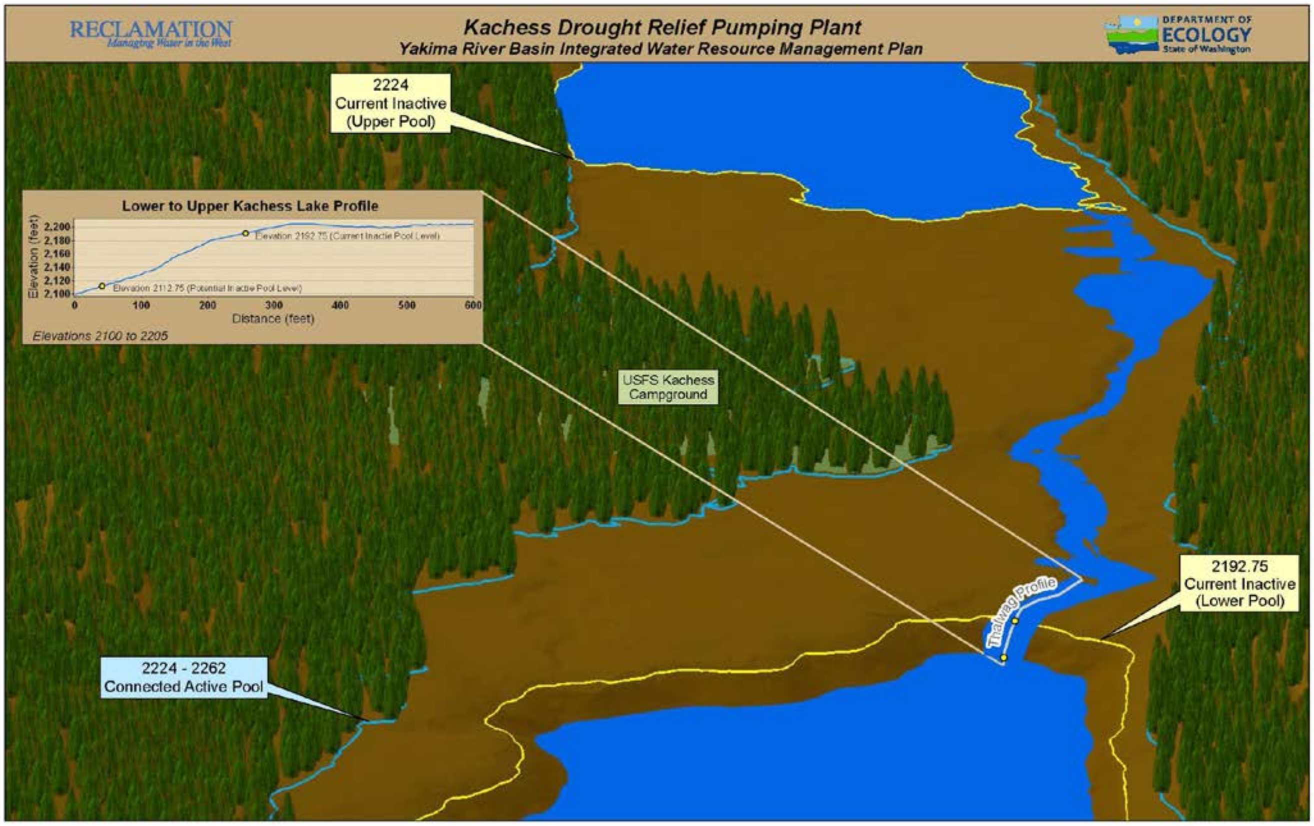

Figure 9-8. Profile of lower Kachess reservoir to the lower end of the Narrows. The Narrows continues to upper Kachess Reservoir.

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Appendix B – Photographs

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Figure 9-9. Box Creek Canyon temporary straw bale and visqueen passage channel for adult bull trout, 2003, looking downstream toward the upper reservoir. Built and removed four times in the past 14 years costing approximately $35,000 each time

. **Figure 9-10.** Box Canyon Creek temporary straw bale and visqueen passage channel for adult bull trout, 2003, looking up the creek as the flow is directed into the upper reservoir. It boosts flow depth in the cross-section and prevents creek flow from going subsurface before reaching the reservoir. . Notice the bedrock outcrops along the canyon wall.

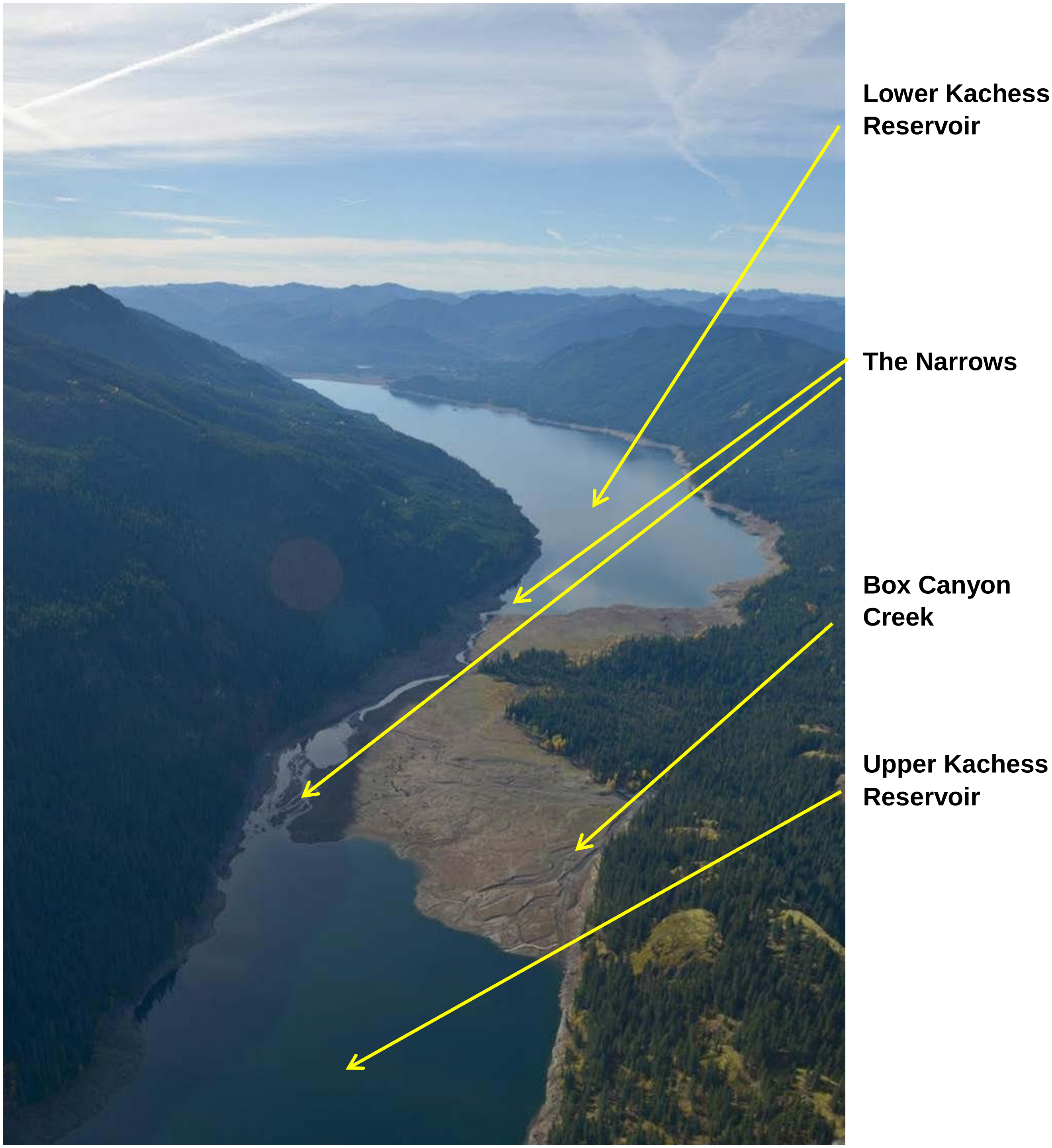

Figure 9-1. Aerial view of lower Kachess Reservoir (top of photo), the Narrows, and Box Canyon Creek streambed flowing toward the upper Kachess Reservoir in a low water year. Photo date: October 2015.

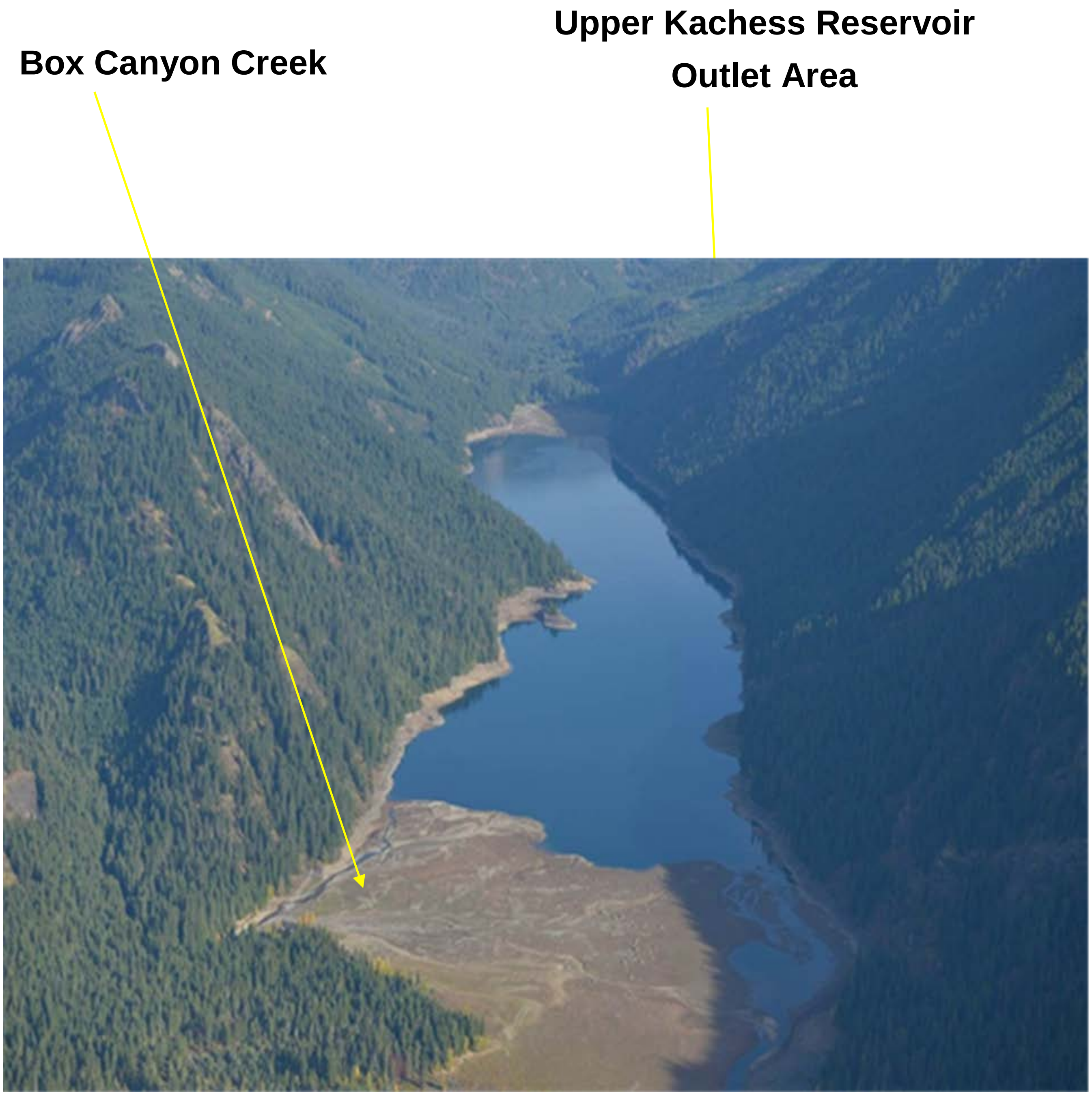

Figure 9-12. Aerial photo of Box Canyon Creek streambed flowing into the upper Kachess Reservoir (bottom left). In the shadows of the photo (right bottom) is the upper reservoir's confluence with the Narrows flowing toward the lower Kachess Reservoir. Photo date: October 2015

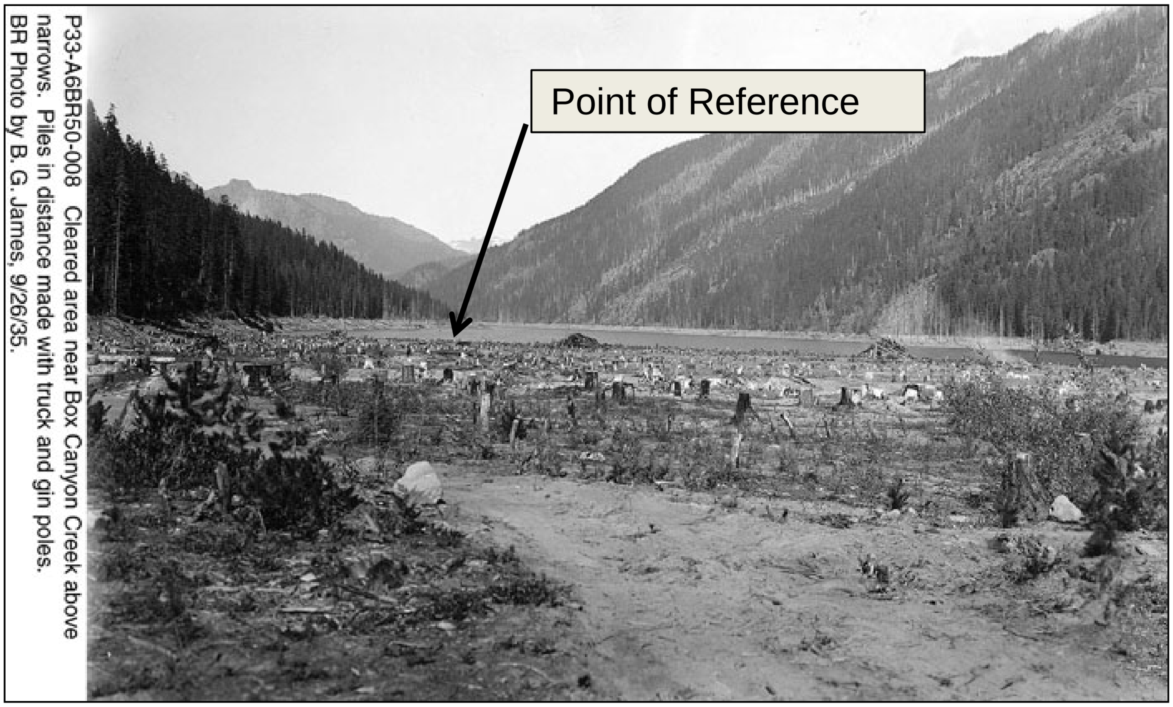

Figure 9-13. 1935 photograph of the alluvial fan at Box Canyon Creek. Notice the many visibly exposed tree stumps.

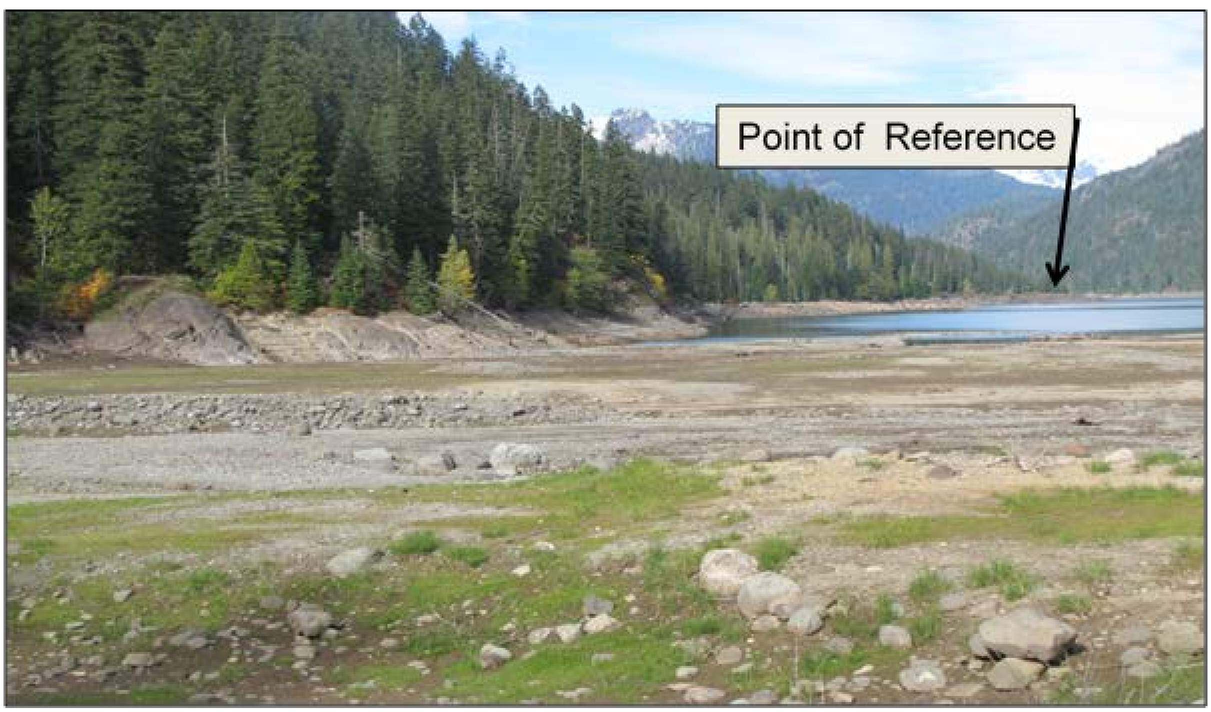

Figure 9-14. Photograph of the alluvial fan at the Box Canyon Creek; compare to the above 1935 photo and notice the absence of visibly exposed tree stumps. Photo date: 2013.

Figure 9-15. The Box Canyon Creek channel is mostly cobble, boulder, and gravel with pockets of sand in lower velocity areas.

Figure 9-16. Near the confluence, the alluvial fan at Box Canyon Creek is composed of very coarse material.

Figure 9-17. Finer sediments are found farther away from the mouth.

Appendix C – Hydrologic Information

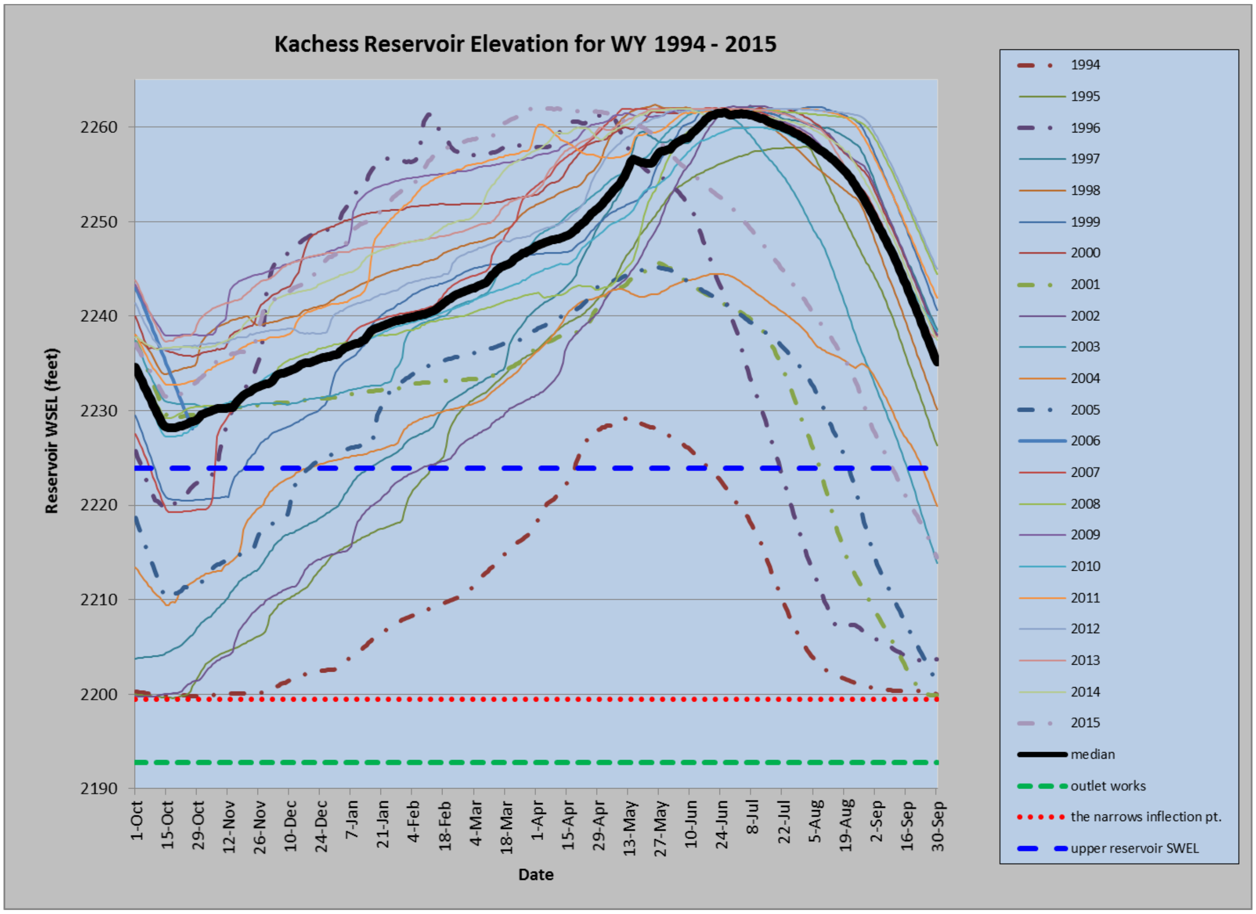

Figure 9-18. Daily mean Kachess Reservoir water surface elevation, water years 1994-2015.

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Appendix D – Hydraulic Data

HEC-RAS Plan: Plan 01 River: BOX CANYON CR. Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1 Foot	6.19	MIN FISH Q	5.00	2262.00	2262.55		2262.56	0.00108	0.49	10.21	21.92	0.13
1 Bridge	6.19	MAX FISH Q	114.00	2262.00	2264.16		2264.21	0.00335	1.85	61.47	41.39	0.27
1	6.19	2-YR	390.00	2262.00	2265.70		2265.82	0.004136	2.88	135.35	54.83	0.32
1 6	6.19	10-YR	799.00	2262.00	2267.05		2267.26	0.004655	3.67	217.46	66.66	0.36
1	6.19	50-YR	1341.00	2262.00	2268.32		2268.61	0.004805	4.34	309.04	75.80	0.38
1	6.19	100-YR	1637.00	2262.00	2268.87		2269.21	0.004744	4.67	351.34	77.18	0.38
1	4.81	MIN FISH Q	5.00	2262.00	2262.19	2262.10	2262.20	0.012187	0.88	5.67	30.89	0.36
1	4.81	MAX FISH Q	114.00	2262.00	2262.90		2263.14	0.031772	3.92	29.07	34.33	0.75
1 5	4.81	2-YR	390.00	2262.00	2263.65	2263.65	2264.40	0.047862	6.95	56.12	37.92	1.01
1	4.81	10-YR	799.00	2262.00	2264.60	2264.60	2265.72	0.042171	8.50	94.05	42.44	1.01
1	4.81	50-YR	1341.00	2262.00	2265.57	2265.57	2267.04	0.038844	9.76	137.44	47.09	1.01
1	4.81	100-YR	1637.00	2262.00	2266.03	2266.03	2267.66	0.037249	10.23	159.98	49.33	1.00
1	3.31	MIN FISH Q	5.00	2258.00	2258.09	2258.09	2258.13	0.118180	1.65	3.04	35.64	0.99
1	3.31	MAX FISH Q	114.00	2258.00	2258.90		2259.07	0.023355	3.31	34.40	41.73	0.64
1	3.31	2-YR	390.00	2258.00	2260.07		2260.37	0.015493	4.42	88.29	50.87	0.59
1 4	3.31	10-YR	799.00	2258.00	2261.17		2261.60	0.014689	5.23	152.80	65.63	0.60
1	3.31	50-YR	1341.00	2258.00	2262.12		2262.70	0.014770	6.07	221.26	78.93	0.63
1	3.31	100-YR	1637.00	2258.00	2262.51		2263.17	0.014391	6.51	253.45	86.08	0.63
1	2.50	MIN FISH Q	5.00	2256.00	2256.45		2256.46	0.004413	0.83	6.03	16.76	0.24
1	2.50	MAX FISH Q	114.00	2256.00	2257.85		2257.96	0.008833	2.57	44.28	37.80	0.42
1 3	2.50	2-YR	390.00	2256.00	2259.06		2259.30	0.010905	3.99	97.79	50.55	0.51
1	2.50	10-YR	799.00	2256.00	2260.14		2260.54	0.011511	5.04	158.83	64.26	0.55
1	2.50	50-YR	1341.00	2256.00	2261.12		2261.67	0.010863	6.03	235.52	93.44	0.56
1	2.50	100-YR	1637.00	2256.00	2261.56		2262.17	0.010474	6.40	280.03	106.78	0.56
1 Bluff	0.56	MIN FISH Q	5.00	2254.50	2254.98		2255.00	0.015435	1.19	4.22	17.58	0.43
1	0.56	MAX FISH Q	114.00	2254.50	2256.21		2256.28	0.008358	2.16	52.70	56.29	0.39
1	0.56	2-YR	390.00	2254.50	2257.26		2257.44	0.008373	3.38	115.39	62.86	0.44
1 2	0.56	10-YR	799.00	2254.50	2258.28		2258.58	0.008656	4.37	182.91	69.25	0.47
1	0.56	50-YR	1341.00	2254.50	2259.21		2259.66	0.009598	5.36	250.20	75.08	0.52
1	0.56	100-YR	1637.00	2254.50	2259.58		2260.12	0.010472	5.88	278.17	77.37	0.55
										USE FOR ROCK	SIZING	
1 Mouth	0.00	MIN FISH Q	5.00	2254.00	2254.60	2254.33	2254.61	0.003918	0.69	7.20	24.00	0.22
1	0.00	MAX FISH Q	114.00	2254.00	2255.90	2255.15	2255.94	0.004361	1.58	72.19	76.00	0.29
1	0.00	2-YR	390.00	2254.00	2257.00	2255.87	2257.08	0.004278	2.28	171.25	102.50	0.31
1 1	0.00	10-YR	799.00	2254.00	2258.10	2256.48	2258.21	0.003828	2.68	297.66	128.00	0.31
1	0.00	50-YR	1341.00	2254.00	2259.10	2257.07	2259.24	0.003862	3.04	440.67	158.00	0.32
1	0.00	100-YR	1637.00	2254.00	2259.50	2257.36	2259.66	0.003996	3.23	506.25	170.00	0.33

Figure 9-19. Summary of the HEC-RAS analysis for Box Canyon Creek conducted for the 2008 Box Canyon Creek Appraisal Report

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Appendix E – Option Drawings

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Figure 9-20. OPTION 1 - Box Canyon Creek: Concrete Open Channel on West Side conceptual drawing.

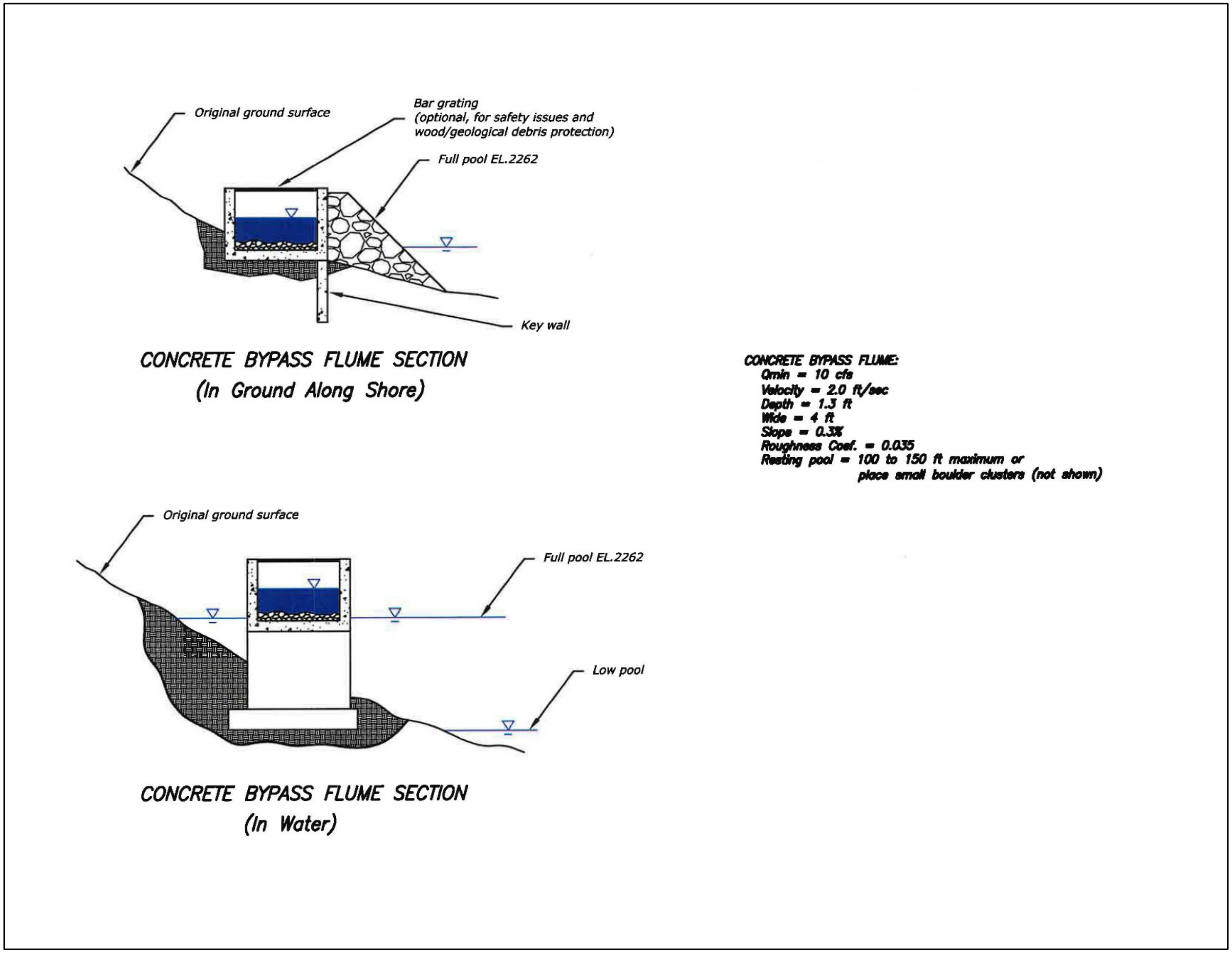

Figure 9-21. OPTION 1 – Box Canyon: Concrete Open Channel on West Side showing the profile view of the infiltration gallery, stoplog and concrete bypass flume.

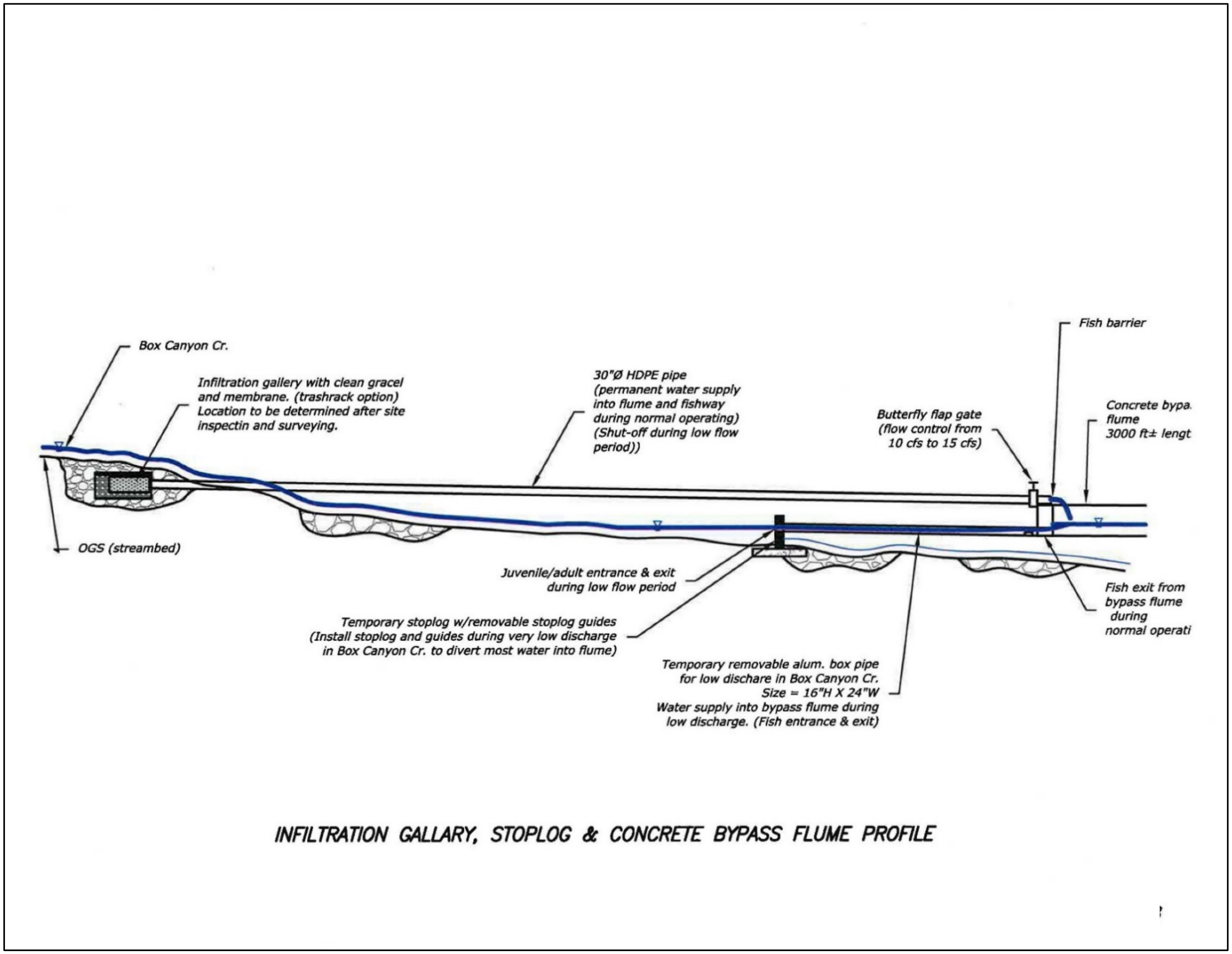

Figure 9-22. OPTION 1 –Box Canyon: Concrete Open Channel on West Side showing the steeppass fishway that would guide fish from the reservoir to the downstream end of the concrete flume.

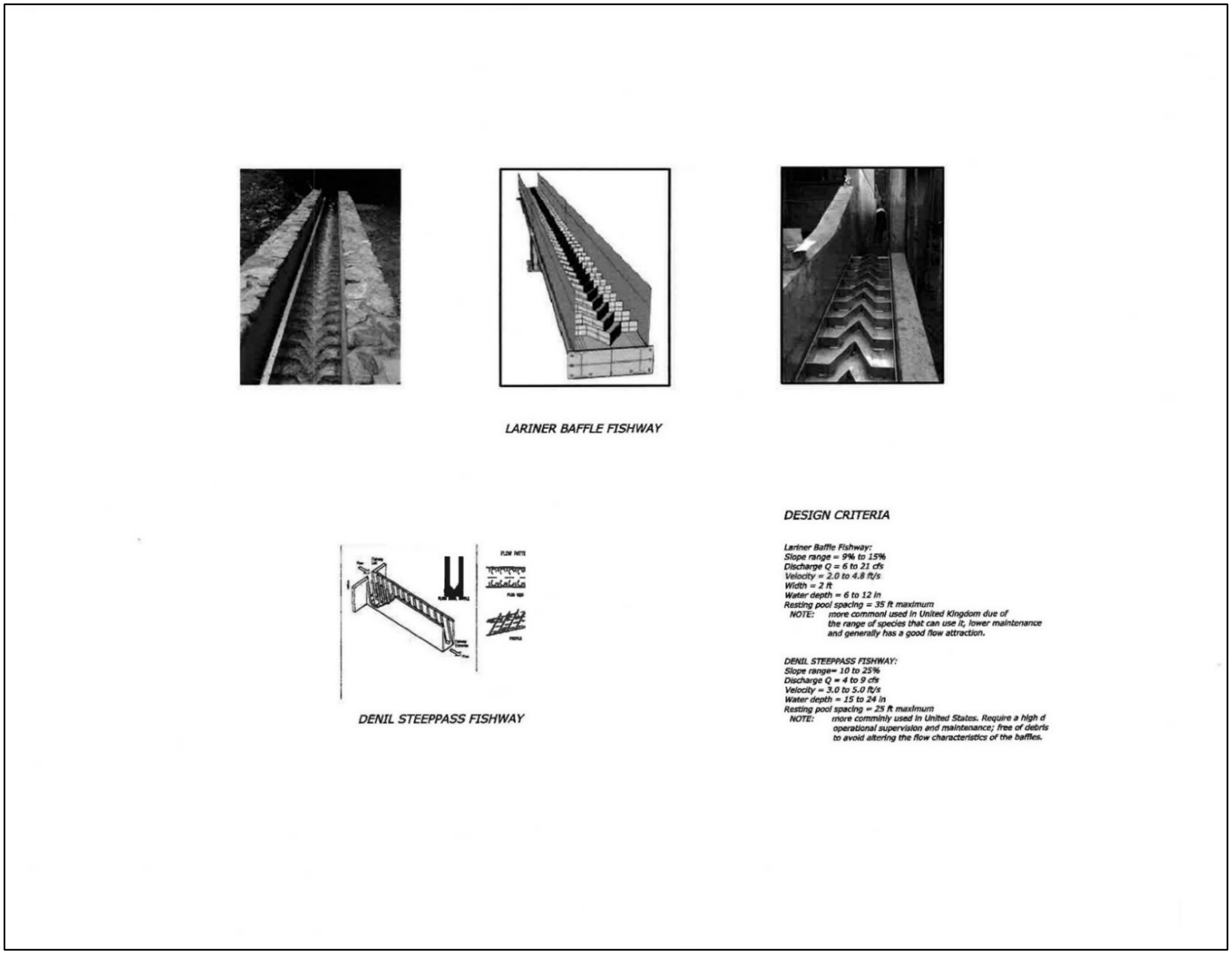

Figure 9-23. OPTION 1 –Box Canyon: Concrete Open Channel on West Side showing the steeppass fishway that would guide fish from the reservoir to the downstream end of the concrete flume

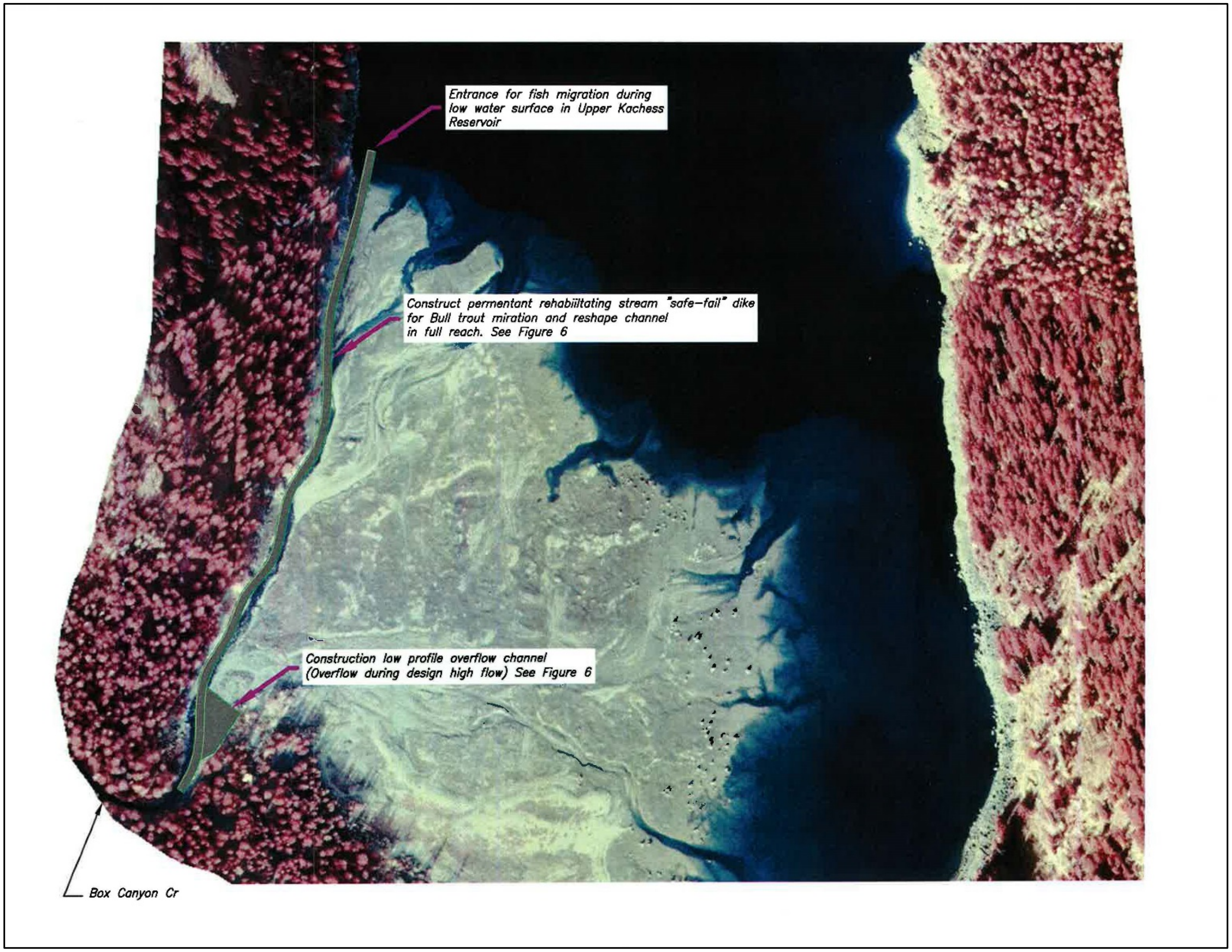

Figure 9-24. OPTION 2 - Box Canyon: Roughened Channel conceptual drawing.

Figure 9-25. OPTION 2 – Box Canyon Roughened Channel would be designed similar to the Bruton channel on lower Taneum Creek **above.**

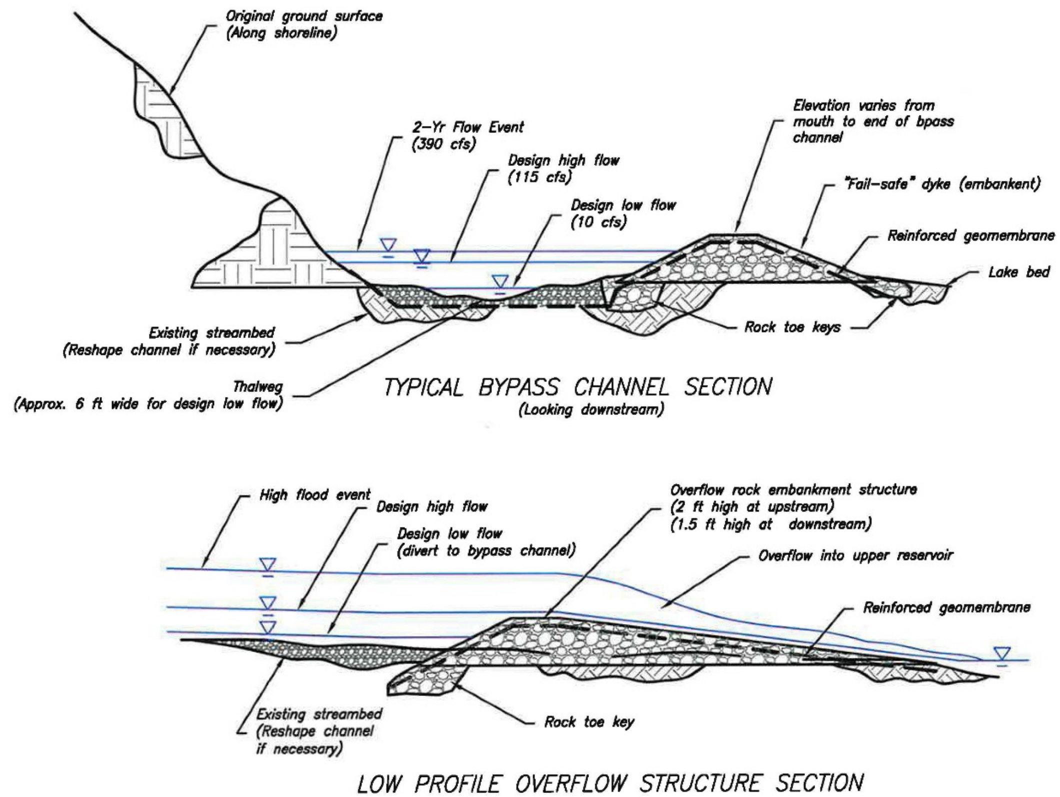

Figure 9-26. OPTION 2 - Box Canyon: Roughened Channel. Typical bypass channel and low profile overflow structure cross sectional view.

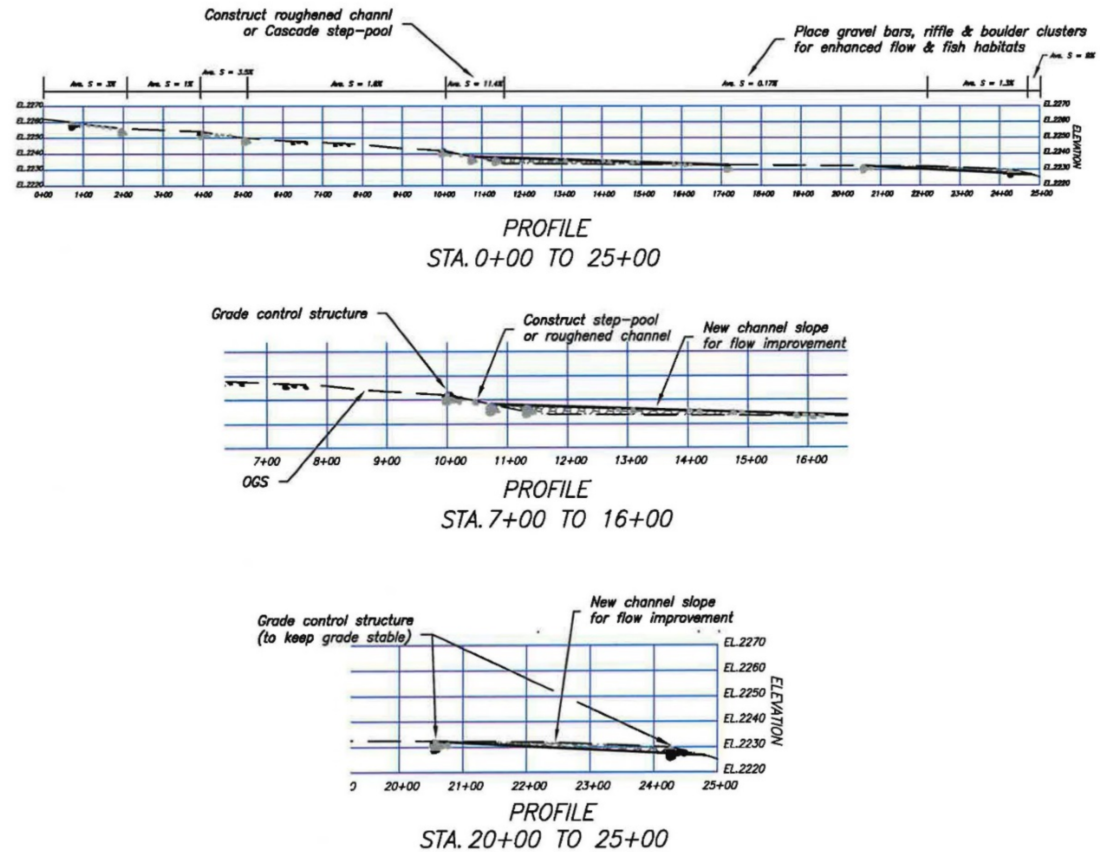

Figure 9-27. OPTION 2 – Box Canyon: Roughened Channel profiles of existing creek channel.

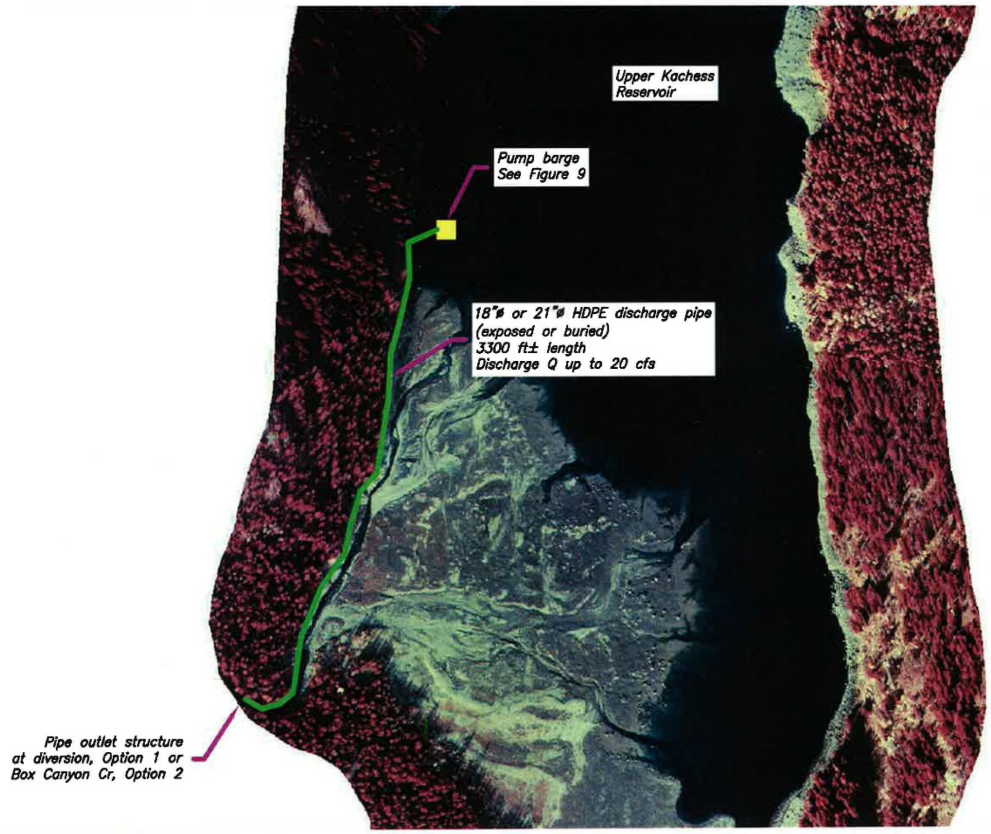

Figure 9-28. OPTION 3 - Box Canyon: Water Pumped from Upper Reservoir conceptual drawing.

Figure 9-29. OPTION 4 - The Narrows: Lower to Upper Reservoir Passage - Gravity Flow from Mineral Creek conceptual drawing.

Figure 9-30. OPTION 5 - The Narrows: Lower to Upper Reservoir Passage - Electric Pump conceptual drawing.

Figure 9-31. OPTION 6 - The Narrows: Lower to Upper Reservoir Passage -Natural Channel conceptual design.

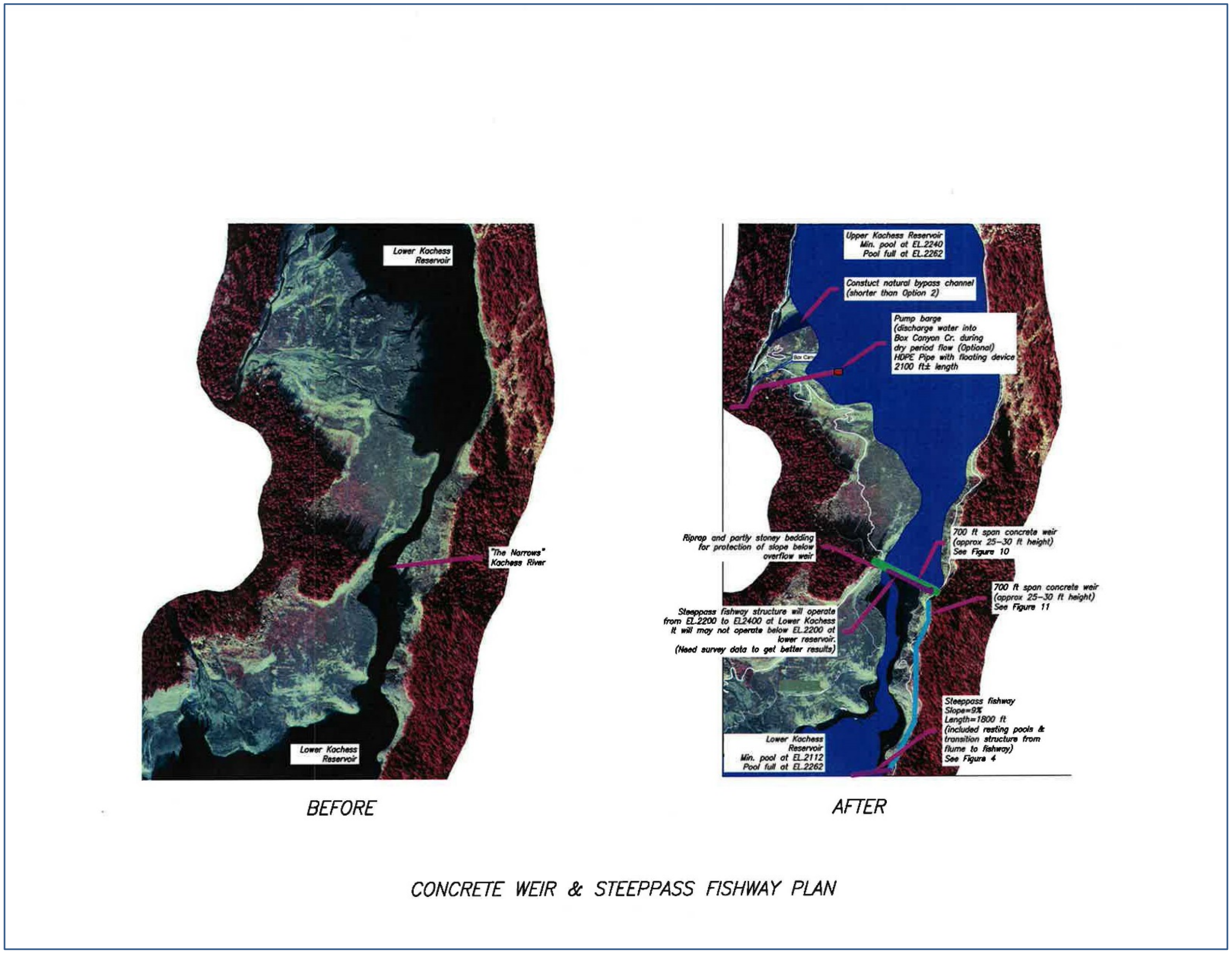

Figure 9-32. OPTION 7 - The Narrows: Full Span Concrete Weir and Fishways cross sectional view of channel design.

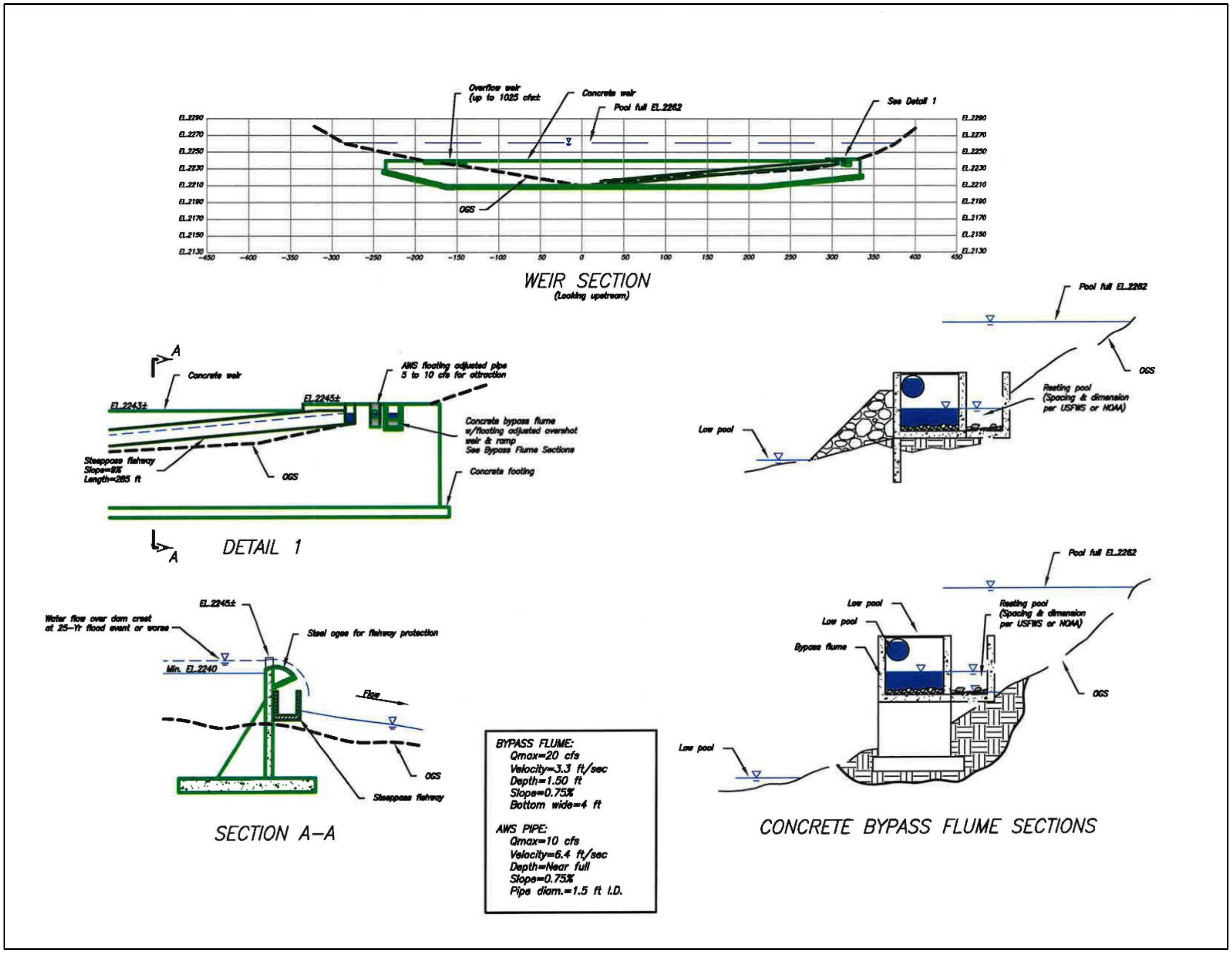

Figure 9-33. OPTION 7 - The Narrows: Full Span Concrete Weir and Fishways cross sectional view of channel design

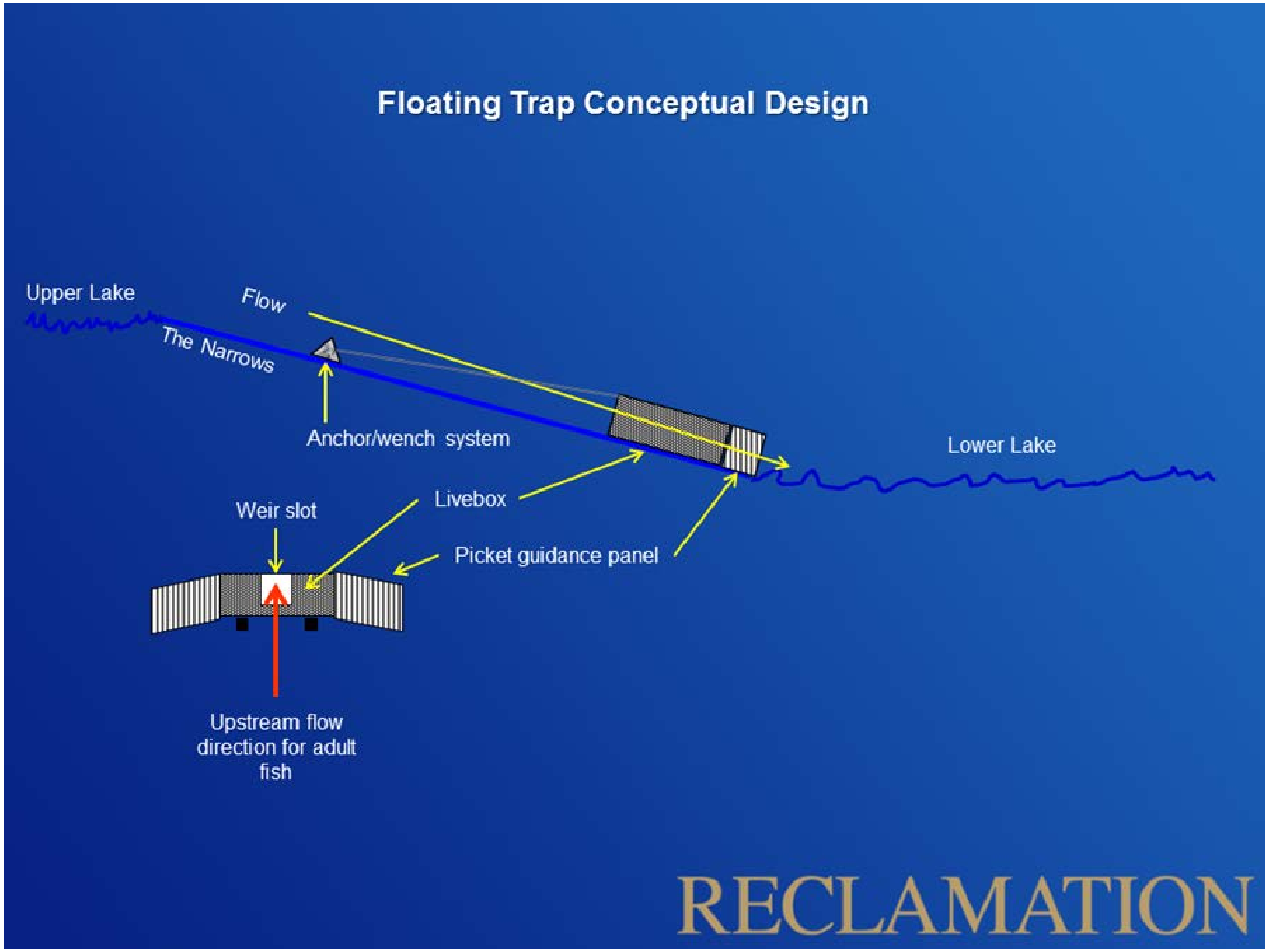

Figure 9-34. OPTION 8 - The Narrows: Fish Trap-and-Haul System conceptual design for floating trap.

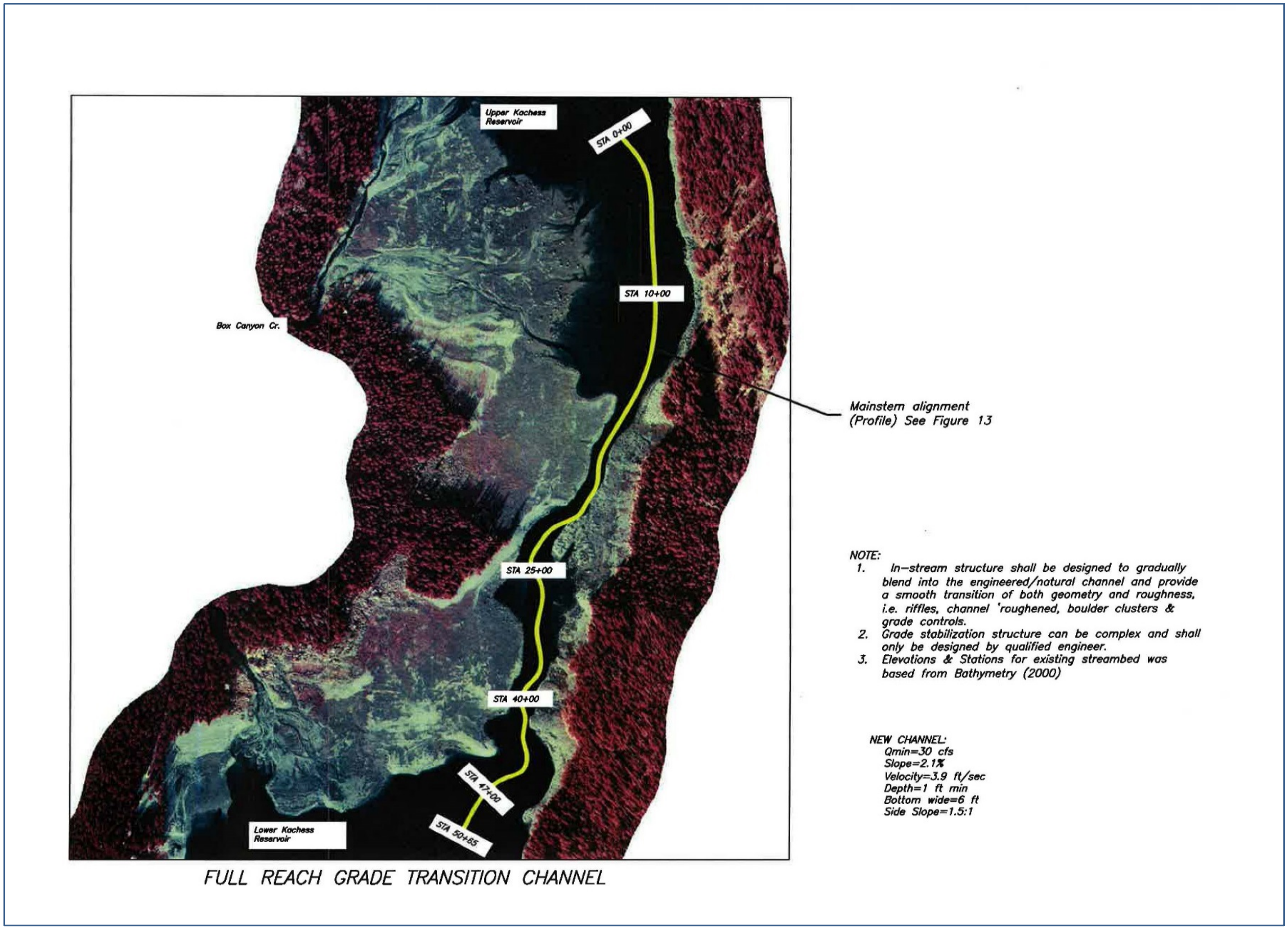

Figure 9-35. OPTION 9 - The Narrows: Full Reach Grade Control Structures

Appendix F – Cost Estimates

Option	Title	Cost
1	Box Canyon: Concrete Open Channel on West Side	$2,189,388.20
2	Box Canyon: Roughened Channel	$1,912,197.00
3	Box: Canyon: Water Pumped from Upper Reservoir	To be determined
4	The Narrows: Lower to Upper Reservoir Passage - Gravity Flow from Mineral Creek	Rejected
5	The Narrows: Lower to Upper Reservoir Passage - Electrical Pump	Rejected
6	The Narrows: Lower to Upper Reservoir Passage - Natural Channel	Rejected
7	The Narrows: Full Span Concrete Weir and Fishways	$12,888,419.64
8	The Narrows: Fish Trap-and-Haul System	To be determined
9	The Narrows: Full-Reach Grade Control Structures	