Yakima River Basin Integrated Water Resource Management Plan

Technical Memorandum:

Screening of Alternatives for the Keechelus-to-Kachess Conveyance Project

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ

Prepared by

HDR Engineering, Inc
Anchor QEA

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

September 2013

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1.0 Introduction

This technical memorandum describes the alternatives that were developed and evaluated to convey water from Reclamation's Keechelus Reservoir to Kachess Reservoir as part of the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan). The purpose of the Keechelus to Kachess (K-to-K) flow transfer is to better utilize the storage volumes in these two reservoirs to meet the goals of the Integrated Plan and to reduce high flows at certain times of year in the Yakima River below Keechelus Reservoir.

The goals of the Integrated Plan are to protect, mitigate and enhance fish and wildlife habitat; provide increased operational flexibility to manage in-stream flows to meet ecological objectives; and improve the reliability of the water supply for irrigation, municipal supply and domestic uses (Reclamation and Ecology, 2012b).

The K-to-K Conveyance Project is located near Snoqualmie Pass and Interstate-90 (I-90) approximately 41 miles northwest of Ellensburg, Washington (Figure 1-1).

Figure 1-1. K-to-K Conveyance Project Location

The K-to-K Conveyance project has two purposes: 1) to improve fish habitat conditions by reducing flows in the upper 10.3 miles of the Yakima River below Keechelus Dam during periods of high reservoir releases; and 2) to enable the storage of more runoff from Keechelus Reservoir drainage to provide additional water supply for agricultural irrigation and other uses.

Transferring water from Keechelus to Kachess Reservoir would improve rearing conditions for steelhead and spring Chinook by reducing artificial summer high flows in the Yakima River between Keechelus dam and the mouth of the Kachess River. Currently the flows are higher than natural conditions during summer months when water is released from the reservoir for irrigation. The improved rearing conditions would contribute to improved survival and productivity of the species. The project would also increase water levels in Kachess Reservoir most years. The increased reservoir levels are expected to improve bull trout passage to tributary streams which is currently impaired by low reservoir levels. Increased flow releases from Kachess Reservoir would improve instream flow and habitat quality for salmonids in areas downstream of the reservoir.

Keechelus Reservoir has inadequate storage capacity in comparison with its drainage basin, and Kachess Reservoir has excess storage capacity in comparison with its drainage basin. The K-to-K Conveyance project will help to balance storage between these two reservoirs, thereby increasing the total amount of runoff that can be captured by the storage system overall.

Modeling of the Yakima River system using Reclamation's RiverWare model indicates a median quantity of 97,000 acre-feet of water can be transferred from Keechelus Reservoir to Kachess Reservoir annually. The quantities will vary considerably from year to year and range from approximately 10,000 acre-feet in years with low runoff to as high as 130,000 acre-feet in years with high runoff.

The K-to-K Conveyance project is currently at a conceptual stage of development. A previous technical memorandum describing initial project criteria and one pipeline conveyance alternative was issued in 2011 (Reclamation and Ecology, 2011b). The purpose of this alternatives screening technical memorandum is to document the additional conveyance route alternatives and project configurations that have been identified and evaluated for this project; and then to determine which of these alternatives should be further evaluated for selecting a preferred route.

2.0 Project Criteria

2.1 K-to-K Transfer Flow Rate

For purposes of this route alternatives analysis, the preliminary capacity of the conveyance system has been retained from prior analysis in Reclamation and Ecology 2012b. This is an average capacity of 400 cubic feet per second (cfs) and a maximum of 500 cfs. This flow rate is intended to enable Reclamation to reduce flows in the upper Yakima River to 500 cfs beginning in July each year between Keechelus Dam and Lake Easton (approximately 10.3 river miles). Flow in this reach is controlled primarily by releases from Keechelus Reservoir. The flow rate in this reach of the Yakima River would then be ramped down from 500 cfs in early August to 120 cfs by early September. To improve the fish habitat conditions for fish in this reach of the Yakima River, the year-round base flow in that reach of the river would be increased to 120 cfs.

Further investigation and optimization of the conveyance capacity required to meet instream flow and water supply objectives should be considered prior to beginning preliminary design.

2.2 Keechelus Reservoir K-to-K Transfer Water Level

The lowest Keechelus Reservoir water level during operation of the K-to-K conveyance was estimated using two approaches. The first approach was to review the results of the RiverWare modeling performed for the Integrated Plan in 2011. The results for the May through September irrigation season were reviewed, as well as for the entire year. According to the RiverWare results, diversions into the K-to-K conveyance could occur with reservoir pool elevations as low as Elevation (El.) 2430. Those low lake levels could occur during October after a severe drought as water is diverted to Kachess Reservoir to balance water storage. During the May-through-September timeframe, the lowest Keechelus Reservoir water level during a K-to-K flow transfer is El. 2469. Further review of the modeled refill operations indicate that refill would not be necessary at the low Keechelus Reservoir water levels shown in the RiverWare results. This is because after drought years, Lake Keechelus would need to refill and water transfers to Kachess Reservoir could be delayed to later in winter after Keechelus Reservoir refill has occurred. The model indicated that a K-to-K flow transfer in October is a hydrologic modeling issue that can be adjusted so that transfers are shown to occur only when Keechelus Reservoir has sufficient volume to provide water transfers to Kachess Reservoir.

The second approach to estimate the lowest Keechelus Reservoir flow transfer elevation was to review current operations and assume some additional volume of water would be required to meet Yakima River fall and winter instream flows downstream of Keechelus Reservoir. The additional volume of water would be released through the existing dam outlet to the Yakima River. Reclamation currently releases a minimum of approximately 80 cfs from Keechelus Reservoir to the Yakima River during fall and winter months (September through March). The Integrated Plan identifies a goal of increasing these minimum fall and winter instream flows to 120 cfs.

The typical range of Keechelus Reservoir elevations for water years 1990-2012 during the expected flow transfer period was from the spillway crest El. 2517 (10 percent exceedence on July 1) to El. 2435 (90 percent exceedence on September 8). The lowest possible lake elevation is set by the existing outlet structure at El. 2425. The minimum active pool storage volume (above El. 2425) in recent years has been about 10,000 acre-feet, which occurred in the drought years 2001 and 2005. Increasing the instream flows in the Yakima River to 120 cfs in the fall and winter would require an additional 16,600 acre-feet of active pool storage in Keechelus Reservoir – for a total active pool volume of approximately 27,000 acre-feet, assuming that little inflow occurs during that period.

Based upon Reclamation’s storage capacity curve for Keechelus Reservoir, approximately 27,000 acre-feet of active pool storage would remain with the lake water surface at El. 2445. Therefore, the minimum lake level for transferring water from Keechelus Reservoir to Kachess Reservoir was set at El. 2445. In summary, because additional Keechelus storage volume is needed to provide the 120 cfs base instream flows in the Yakima River, the K-to-K flow transfer outlet would not need to function below that El. 2445.

2.3 Potential for Hydropower Generation

The potential for the generation of hydropower from the K-to-K transfer was briefly evaluated and deemed as being infeasible for the following reasons:

- The facility would only be operated periodically during the periods of time when water is being transferred (about half the time on average).
- The available flow rates would vary and would usually not be up to the full hydraulic capacity of the hydropower facility.
- Adding hydropower would add cost to the pipeline and/or tunnel to allow for the dynamic surge conditions that could occur under hydropower operations.
- A new substation and electrical transmission lines back to high voltage lines in the I-90 corridor would likely be required – at significant additional cost.
- Even though the facility would only be operated periodically, the mechanical and electrical components of the hydropower facility would require continuous and ongoing maintenance.

As a result of these issues, the costs of the hydropower facility would likely be on the order of two-to-three times higher than economically feasible based upon the potential benefits. Therefore, the potential for hydropower generation was not considered further as a design criterion.

2.4 Other Criteria

Other criteria used to develop and compare conveyance alternatives are as follows:

- Rely on gravity flow (no pumping).
- Minimize capital and operations and maintenance (O&M) costs.
- Minimize negative environmental or public impacts.
- Coordinate with Washington State Department of Transportation (WSDOT) I-90 highway reconstruction project planned for an area near Keechelus Dam.

3.0 Original Pipeline Alternative Concept

During the original conceptual development of the K-to-K Conveyance project, the HDR consulting team considered a single route using a shallow, buried pipeline with a diameter of 80 to 86 inches (Reclamation and Ecology 2011b). Figure 3-1 shows the original route, labeled as Pipeline Alternative 1 (Alternative P1) shown in yellow. Figure 3-2 also shows additional route alternatives that have been identified for purposes of this technical memorandum.

The Alternative P1 route begins at the existing Keechelus Dam outlet works and runs along the north side of the Yakima River and parallel to I-90 before crossing under I-90. Once on the east side of I-90, the pipeline would cross open and forested areas to intersect Lake Kachess Road. After intersecting the road, this route continues along the shoulder of the road until reaching the discharge point on the west shoreline of Kachess Reservoir. The Alternative P1 pipeline had an estimated length of approximately 26,000 feet.

The original concept assumed that fish screens would be added to the existing Keechelus Dam tower outlet structure and that the existing outlet channel would be partially lined and pressurized. Pressurizing the conduit to Keechelus Reservoir water surface elevation was necessary to provide the head required to force water over a high point in the pipeline route. To maintain the gravity flow, a deep open trench cut or short section of tunnel would still be required at the high point of the pipeline route along Lake Kachess Road.

This concept also assumed that for discharging into the Kachess Reservoir the high-pressure pipeline would connect to an energy-dissipating pipeline and diffuser that would extend into the Kachess Reservoir to discharge below the low-water elevation in the Kachess Reservoir.

4.0 Agency Meetings

4.1 US Forest Service

Washington Department of Ecology), Reclamation, and HDR team members met with US Forest Service (USFS) staff in Cle Elum on February 23, 2012. The HDR team described Pipeline Alternative 1 as shown on Figure 3-1. During the meeting, USFS staff expressed the following concerns about the proposed pipeline alignment:

- The pipeline as presented would disturb high-value habitat between the Yakima River and I-90 and an important wildlife migration corridor. They did not want to create any new impediments to the use of that habitat, impede migration, or affect planned restoration of hydrologic connectivity between the hillside slope and the Yakima River floodplain.
- Construction of this magnitude would disrupt traffic along the Lake Kachess Road and restrict access to a large USFS campground at Kachess Reservoir.
- The shoreline area near the proposed pipeline outlet into Kachess Reservoir potentially contains prehistoric cultural resource sites that could be disturbed by construction of the pipeline and outlet structure.

The USFS asked that the team consider an alternate pipeline route to the west along the base of Keechelus Dam and then south and west, using existing USFS roads NF-5400 and/or NF-5480 and via other disturbed areas. This alternative route – also shown on Figure 3-1 was subsequently investigated as Pipeline Alternative 2 (P2) is discussed in Section 6 below.

4.2 Washington Department of Transportation

Ecology, Reclamation, and the HDR team also met with WSDOT representatives in Yakima on March 13, 2012. The team presented the K-to-K routing analysis and discussed opportunities to coordinate with WSDOT regarding the pipeline crossing of I-90. WSDOT staff provided more information about the planned reconstruction and regrading of I-90 in the area – which would allow for proposed wildlife crossings under I-90.

Although the original concept had been to use one of the planned wildlife undercrossing locations for the pipeline, WSDOT staff commented that it would probably be preferable that the pipeline be installed under the highway during the placement of new fill material for the highway as part of the highway reconstruction project. This approach has been incorporated in the pipeline alternatives as discussed in Section 6 below. WSDOT indicated I-90 improvements at the pipeline crossing location had not yet been funded. WSDOT also provided geotechnical reports and drill logs for their work along I-90 in the Lake Keechelus area.

5.0 Site Reconnaissance

Two site reconnaissance visits were made to the K-to-K project area in 2012 to observe the alternative routes and to evaluate locations for preliminary exploratory geotechnical drilling.

5.1 July 17, 2012, Site Visit

Three HDR team members met with two Reclamation geologists on July 17, 2012, to tour K-to-K and Kachess Inactive storage alternative routes. The group first visited Keechelus Dam to view and discuss options for diverting water from Keechelus Reservoir and for locating a tunnel portal in the area. The group then went down river to tour the Crystal Springs Campground site as a potential portal location. Finally, they drove the Lake Kachess Road to Kachess Reservoir to view potential locations for a tunnel portal at Kachess Reservoir.

The primary observations from this site visit were as follows:

- It was determined that the concept of diverting from the existing Keechelus Dam outlet, as shown in Reclamation and Ecology 2011b (Alternative P1) would be extremely difficult due to the deep local excavations that would be required to tie in as well as impacts to the Reclamation toe-of-dam drainage improvements that were constructed in 2000.
- Rock outcrops were observed in the Keechelus Dam spillway area that indicate it would likely be feasible to excavate a portal into rock to be able to begin or terminate a rock tunnel in the area.
- Rather than use the existing deep outlet, it would likely be feasible to locate a new intake from Keechelus Reservoir near the spillway north of the existing outlet.
- Rock outcrops were observed in the Crystal Springs Campground area approximately 8,000 river feet downstream of the Keechelus Dam outlet indicating that it would likely be feasible to locate a rock tunnel portal in the campground area.
- Rock outcrops were observed along the Lake Kachess Road near Kachess Reservoir, indicating that it would likely be feasible to locate a rock tunnel portal in the area adjacent to Lake Kachess Road.

5.2 October 29, 2012, Site Visit

Three HDR team members and a drilling subconsultant met with two Reclamation staff members and a USFS representative at the K-to-K site on October 29, 2012. The primary purpose of this site visit was to view two potential geotechnical boring locations for the Tunnel Alternatives T1 and T2. These alternatives are described in Section 6 below.

The primary observations from this site visit were as follows:

- Rock outcrops were observed at the proposed the Kachess Reservoir portal location.
- Based upon area topography it was evident that Lake Kachess Road could be temporarily rerouted to allow more room for construction in the Kachess Reservoir portal area.

- It would be feasible to install two planned geotechnical borings – one near the proposed Kachess Reservoir portal site and one at an intermediate site along the Tunnel Alternatives T1 and T2 routes on Road NF-4936 as shown in Figure 3-1.
- Further observations of rock outcrops in the proposed Keechelus Reservoir tunnel portal area indicated that there should be rock at depth in either Alternative T1 or T2 portal areas.

A review of Reclamation Keechelus Dam and WSDOT I-90 geotechnical reports also confirmed that previous geotechnical explorations in the area had encountered bedrock.

6.0 New Conveyance Route Alternatives

6.1 Additional Pipeline Alternatives

Figure 3-1 shows plan views of all of the additional pipeline route alternatives that have been considered for K-to-K conveyance and are discussed below.

6.1.1 Pipeline Alternative P2

After the USFS meeting, Pipeline Alternative 2 (Alternative P2) was developed to avoid sensitive areas by following existing USFS roads NF-5480 and NF-5400. The pipeline would begin at the existing outlet works and then continue to the southwest along the treeline below the dam, then turn to the southeast and finally to the northeast along USFS roads to the I-90 crossing in a line with NF-5400 northwest of the I-90 Interchange 62. This route would then intersect and be adjacent to Lake Kachess Road all the way to a discharge or outfall structure at Kachess Reservoir. With a total length of about 35,000 feet, Alternative P2 is approximately 9,000 feet longer than Alternative P1.

A review of the profile for the Alternative P2 route revealed that, because of the high topographic elevations along NF-5480, this alternative would not be feasible as a gravity-flow pipeline. As a result, Pipeline Alternative 3 (Alternative P3) was developed to provide a technically feasible pipeline alternative for comparison to one or more tunnel alternatives.

6.1.2 Pipeline Alternative P3

This route is similar to Alternative P1, except that it was modified to connect to a new Keechelus Reservoir outlet structure to mitigate concerns regarding excavating and connecting a pressurized conduit to the existing Keechelus Dam outlet channel. For Alternative P3, the outlet structure would be connected to a siphon pipeline at the north end of the dam. Alternatively, a deep trenchless construction method could be considered to connect to a new Keechelus Reservoir outlet structure. The upper reach of Alternative P3 was rerouted in an attempt to minimize habitat impacts near the dam, then to more closely parallel I-90, and then to use already disturbed areas (roads and campsites) through the closed USFS campground at Crystal Springs near I-90, Exit 62. Due to USFS budgetary limitations, the campground is permanently closed and scheduled for decommissioning. This new routing would have to be reviewed with the USFS to determine if it addressed their concerns for construction through this area.

As with Alternative P2, this route would then cross under I-90 in a line with USFS road NF-5400 near the campground and then continue to the east to intersect with Lake Kachess Road. The I-90 crossing would either be a trenchless crossing under the existing freeway grade or an open cut buried pipeline if constructed as part of the WSDOT I-90 regrading project. The route would then intersect and extend along Lake Kachess Road all the way to a discharge structure or outfall at Kachess Reservoir. With a total length of approximately 29,000 feet, this route is approximately 3,000 feet longer than Alternative P1.

In spite of rerouting the upper end of the alignment, Alternative P3 would still require construction activities in the sensitive area between the Yakima River and I-90 and along Lake Kachess Road.

6.2 Initial Tunnel Alternatives T1 and T2

Initial tunneling concepts showed a tunnel route with two intermediate portal locations accessible from Lake Kachess Road. Subsequent discussions with team tunneling experts indicated that the tunnel could likely be constructed in a single drive using a TBM with a diameter of 10 to 12 feet – so that intermediate portals (shafts) would not be necessary.

The need for an intermediate ventilation shaft should be evaluated in subsequent design stages. The evaluation should compare its cost to the costs of extending ventilation ducting with fans from the portal; and the associated energy costs to move air through a longer ventilation duct. Because of the depth of an intermediate shaft, a contractor may choose to extend the ventilation ducting from the mining portal. Following construction, temporary ventilation fans could be used during routine inspections and maintenance of the tunnel.

Tunnel Alternatives 1 and 2 (T1 and T2) were developed as the shortest length between the Keechelus Reservoir outlet near the north end of the dam and a potential portal site at Kachess Reservoir. The lengths of the deep tunnel segments for Alternatives T1 and T2 are approximately 19,700 feet and 20,100 feet respectively. The only difference between Alternatives T1 and T2 is the Keechelus Reservoir portal location.

A similar length and diameter water supply tunnel (Jollyville) is currently (2013) being constructed in Austin, Texas. The Jollyville tunnel is being mined through rock in three reaches between shafts that are between 220 and 350 feet deep. The longest reach is being mined using a 10.7-foot-diameter Robbins Main Beam TBM for a total distance of 22,000 feet. In this long reach, the contractor plans on installing four parallel rail switches in enlarged sections of the tunnel to facilitate muck handling by allowing muck trains to pass going in opposite directions.

6.3 New Tunnel Alternative T3

Tunnel Alternative T3 was developed as an alternative to diverting water directly from Keechelus Reservoir. A preliminary hydraulics analysis and field investigation revealed that it would be possible to convey flow through a tunnel by gravity from the Yakima River at the USFS Crystal Springs Campground to the Kachess Reservoir. Due to USFS budgetary limitations, the campground is permanently closed and scheduled for decommissioning. For this alternative, water from Keechelus Reservoir would be released to the Yakima River and would flow downstream for 1.5 miles from the Keechelus Dam outlet to the campground site, where it would be diverted from the river into the tunnel (Figure 3-1).

An earlier version of this concept routed this tunnel to the east-northeast but, due to the Kachess Reservoir shoreline development and topography, there was not a good location to terminate the tunnel at the Kachess Reservoir. The revised Alternative T3 route extends to the northeast to the same Kachess Reservoir portal location as Alternative T1.

This alternative provides a 2,000 feet shorter deep tunnel (17,700 feet versus 19,700 feet) than Alternative T1. It would require the construction of a new diversion in the Yakima River at the closed USFS Crystal Springs Campground.

6.4 Tunnel Criteria

Figure 3-1 also shows the tunnel alternatives that were developed in early 2012 after the USFS expressed their concerns about the overland pipeline route, including their preference for Pipeline Alternative P2.

6.4.1 Reclamation-Preferred Tunnel Design Criteria

The tunnel was originally developed as a pressurized tunnel with a relatively steep slope from Keechelus Reservoir to Kachess Reservoir. However, during October 2012 conference calls with Reclamation, the Reclamation Technical Service Center (TSC) staff expressed their preference for a flatter sloped, free-flow (non-pressurized) tunnel. They preferred a free-flow tunnel for this non-hydropower application because it avoided having to manage and design for pressure transients and it made the tunnel easier to operate, drain, inspect, and maintain. In response to that Reclamation preference, the Keechelus Portal shaft was deepened (to approximately 165 feet) and the tunnel profiles flattened to maintain open channel flow (free-flow) within the tunnel. Control gates and a plunge pool in the Keechelus Portal would be used to control the rate of flow into the tunnel.

During a February 2013 conference call with Reclamation TSC staff, the design team stated that they preferred that the tunnel be designed for open channel free-flow conditions. In subsequent comments on the meeting notes, Reclamation TSC clarified that although the preferred a free-flow tunnel, they not would rule out a pressurized tunnel if ground conditions were suitable. The final tunnel configuration will be further evaluated during preliminary design after more geotechnical information is available. Table 6-1 presents Reclamation-preferred tunnel criteria for tunnel design as discussed and provided by Reclamation TSC.

Table 6-1. Reclamation-Preferred Tunnel Design Criteria

CRITERIA	RECLAMATION PREFERENCE
Hydraulic design (pressurized vs. free-flow)	Prefer free-flow (nonpressurized open channel flow) tunnels for all but hydropower applications (a pressurized tunnel may be suitable if deemed more efficient under certain operational and favorable ground conditions)
Minimum inside diameter	7 feet for a lined tunnel and 8 feet for an unlined tunnel
Maximum velocity	Lined: 10 to 20 feet per second (fps) but prefer less than 10 fps; Unlined: less than 5 fps (depending upon rock quality)
Free-flow tunnel minimum slope	0.0001 with a Froude number of less than 0.7 (subcritical flow)
Free-flow maximum depth	Depth over tunnel diameter (D/d) less than or equal to 0.82
Lining	Varies - shotcrete, reinforced concrete, or precast segments; pressurized tunnels may require steel lining at higher pressures and/ or near the entrance – depending upon rock quality, permeability, and modulus of deformation

6.4.2 Tunnel Characteristics

As with the pipeline alternative, the tunnel alternative will convey an average of 400 cfs during flow transfer operation. To allow for operational flexibility, a tunnel capacity of 500 cfs was used for this preliminary hydraulic analysis. The analysis also used Reclamation's free-flow tunnel criteria for maximum depth, Froude number, and velocity.

A tunnel of this length would likely be constructed using a tunnel boring machine (TBM) designed specifically for the anticipated rock conditions. Alternatively the tunnel could be a flat-bottomed horseshoe shape that would be mined using drill-and-blast methods. In either case, it is likely that, depending upon the rock quality encountered, portions of the tunnel would either need to be lined and/or rock bolted for stability. To provide for gravity flow of drainage from the tunnel during construction, the tunnel alternatives assume that the tunnel would be mined upslope from the Kachess Portal (east) to the Keechelus or Crystal Springs Portal (west).

A circular tunnel is expected to be in the 10- to-12-foot-inside-diameter range – due to both hydraulic capacity and tunnel construction logistics. This diameter range is the minimum size that would be required for a tunnel of this length to allow for efficient personnel and equipment access, muck removal, and electrical and ventilation support systems. The construction of the tunnel portal and outlet structure at Kachess Reservoir (see Section 6.5) would be the same as for all of the three tunnel alternatives.

Depending upon the types and qualities of rock encountered, the tunnel may be unlined or more likely have both lined and unlined segments. The tunnel hydraulic capacity will vary depending upon the tunnel interior surface finish. This characteristic is typically described using a Manning's "n" coefficient with the following ranges of values:

Concrete lining:	0.012 to 0.018
Smooth unlined rock:	0.020 to 0.025
Irregular unlined rock:	0.030 to 0.040

Table 6-2 presents the tunnel hydraulic characteristics and slopes for the above range Manning "n" values using the Reclamation hydraulic design criteria for a free-flow tunnel.

Table 6-2. Tunnel Slopes for Range of Manning's n Values

Hydraulic Criteria (in bold) and Flow Characteristics	10' ID Tunnel		12' ID Tunnel	
	D/d = 0.82 **Froude No.= 0.70** **V = 11.9 fps** Q = 820 cfs	**Q ≥ 500 cfs** D/d = 0.82 V = 7.3 fps	**Q ≥ 500 cfs** D/d = 0.57 V = 7.6 fps	**Q ≥ 500 cfs** **V = 5.0 fps** D/d = 0.82
Tunnel Manning's n Value	Max Tunnel Slope (ft/ft)	Tunnel Slope (ft/ft)		Tunnel Slope (ft/ft)
0.012	0.0021	0.0008		0.00030
0.015	0.0033	0.0012		0.00046
0.020	0.0058	0.0022		0.00082
0.025	0.0091	0.0034		0.00128
0.030	0.0132	0.0049		0.00184
0.035	0.0176	0.0067		0.00251

Note: D/d = Depth of flow / inside tunnel diameter; V = flow velocity (feet-per-second); Q = rate of flow (cubic-feet-per-second)

This table illustrates that for a 10- to 12-foot-inside-diameter tunnel for the range of "n" values, the maximum allowable slopes to comply with Reclamation subcritical flow (Froude Number) criteria are steeper than those required to achieve a 500-cfs capacity. For a 10-foot-inside-diameter tunnel, a subcritical velocity of 7.3 fps is required to achieve the 500 cfs capacity. For a 12-foot-inside-diameter tunnel, the 500-cfs flow capacity can be achieved with a velocity of 5.0 fps.

6.5 Keechelus Reservoir Outlet Options

The K-to-K flow transfer would occur when the Keechelus Reservoir water surface is between El. 2517 (spillway crest) and El. 2445. The existing outlet can drain the lake down to El. 2425. The following alternatives have been considered for the Keechelus Reservoir outlet:

- Outlet Option 1 (for pipeline alternatives only): modify the existing Keechelus Dam outlet tower with fish screens and connect a new pipeline to the existing dam outlet channel.
- Outlet Option 2: Construct a new fish screened outlet structure in the lake and a pipeline or tunnel leading from this structure and extending under the north end of the dam (near the spillway).
- Outlet Option 3 for Alternative T3 only: Use the existing Keechelus Dam outlet and construct a new diversion from the Yakima River at the Crystal Springs Campground, approximately 8,000-feet downstream from the existing Keechelus Dam outlet.

For Alternative P3, the elevation of the Keechelus Reservoir water surface is needed to provide adequate pressure to drive the flow over the ridge between Keechelus Reservoir and Kachess Reservoir (Reclamation and Ecology, 2011b). During Reclamation peer review and conference call discussions, Reclamation expressed their concerns with Option 1 above, because it requires pressurizing the existing Keechelus Dam outlet channel through the dam and connecting to a pipeline. During subsequent site reconnaissance visits in July and October 2012, it became clear that a very deep excavation in the area below the dam would be required to connect a new pipeline to the existing outlet works. This would be excavated in an area of recent (2000) Keechelus Dam drainage improvements. Using the existing outlet tower would also require that it be modified with new fish screens. For all of these reasons, the option of using the existing Keechelus Dam outlet works for the K-to-K conveyance project was eliminated from further consideration.

Another tunnel option for using a short retractable crest dam and intake to divert water from the outlet channel about 500 feet downstream of the dam outlet works (near the existing gauging station) via a lined tunnel/pipeline to the Alternative T1 deep tunnel portal was presented and discussed with Reclamation in February 2013. Reclamation elected not to further consider that option.

The remaining two conveyance outlet options are:

- Construct a new fish-screened outlet near the Keechelus Dam spillway for the Alternative P3 or Alternative T1; or
- Use the existing Keechelus Dam outlet and construct a new fish-screened diversion from the Yakima River approximately 8,000-feet downstream of the dam at the Crystal Springs Campground for Alternative T3.

Installing a new intake in Keechelus Reservoir will have issues related to construction within the reservoir, and a new pipe or tunnel penetration of the dam that will need to be discussed and resolved with Reclamation's Dam Safety Office. Installing a new Yakima River diversion will have issues related to environmental protection and leaving the K-to-K diversion flow in the first 8,000 feet of the Yakima River that will need to be discussed and resolved with fisheries agencies and interested parties. Both of these intake options are being carried forward through a "fatal flaw" analysis to determine if there are any issues that would absolutely prevent the option from being constructed.

6.6 Options for Discharge to Kachess Reservoir

The K-to-K conveyance could discharge into Kachess Reservoir either through an open channel spillway or through a pipe/diffuser in the reservoir.

Alternative P3 would have a considerable pressure or "head" to dissipate before the water is discharged into Kachess Reservoir. One concept would be to discharge the end of the pipeline through a bifurcation and two flow control valves into a vertical plunge pool near the Kachess Reservoir shoreline. This plunge pool would then discharge over a weir to a Reclamation Type 9 (Peterka 1978) baffled spillway into Kachess Reservoir.

For Alternatives T1 and T3, it expected that the open channel (free-flow) tunnel would daylight to an at-grade portal. The portal would be used as the entry or mining portal for the tunnel construction – meaning that most of the surface activity for the tunnel construction would occur at this portal.

The tunnel invert at this entrance would be approximately at the Lake Kachess Road grade at El. 2300. The flow would drop from the tunnel through a discharge transition structure to either an open channel double box culvert or parallel pipes under Lake Kachess Road. As with the pipeline alternative above, these pipes or channel would then discharge through a transition into a Reclamation Type 9 (Peterka 1978) baffled spillway and stilling basin and riprap to dissipate the flow velocity energy as the water enters Kachess Reservoir.

7.0 Initial Screening of Alternatives

The criteria presented in Section 2.0 were used to compare and screen the pipeline and tunnel alternatives described above. The alternatives were then modified and/or eliminated based upon reviews and discussions of these criteria with the USFS, Reclamation, and Ecology staff.

7.1 Pipeline Alternative P1

The original 26,000-foot-long pipeline concept as shown in Reclamation and Ecology (2011a) is designated as Alternative P1 in this technical memorandum. USFS staff expressed concerns regarding the alignment of the pipeline between the Yakima River and I-90 due to construction impacts on sensitive old growth areas and a potential trench cutoff of the lateral flow of water from the hillside to the Yakima River; as well as the impacts on the public of open trench construction along Lake Kachess Road. In the May 2012, Peer Review report, Reclamation technical staff also expressed concern regarding pressurizing the existing Keechelus Dam outlet conduit, which would be required with this pipeline concept. **Alternative P1 was eliminated due to the open trench construction impacts.**

7.2 Pipeline Alternative P2

This 35,000-foot-long Alternative P2 was developed to replace Alternative P1 to address USFS concerns regarding the original pipeline alignment. However, a review of the ground profile for this alignment revealed that approximately 1 mile of the route along USFS Road NF-5480 was near or above El. 2500. To install a gravity-flow pipeline (to be able to draw Keechelus Reservoir down to El. 2445) through this mile-long area would require a 60-foot-deep open cut. This alternative also did not address the Reclamation staff concerns about pressurizing the existing Keechelus Dam outlet channel. **Alternative P2 was eliminated due to the length of pipeline (9,000 feet longer than P1) and depth of cut required by the alignment.**

7.3 Pipeline Alternative P3

This 30,500-foot-long (1,500 foot-long Keechelus outlet pipe and 29,000 foot-long transmission pipe) pipeline alternative describes one technically feasible pipeline alternative for comparison to the tunnel alternatives. Although this revised pipeline route is carried forward for environmental and technical review, it will have many of the same issues that concerned the USFS regarding Alternative P1. These include the environmental impacts of open trench construction between the Yakima River and I-90 as well as public residential and traffic disruption from construction along Lake Kachess Road.

7.4 Tunnel Alternatives T1 and T2

These tunnel alternatives were developed in response to USFS concerns regarding overland pipeline routes – both of which would be longer and more costly than the original pipeline concept (Alternative P1). Both tunnel alternatives are the about the same length (Alternative T2 is about 400 feet longer than Alternative T1); the only difference is the Keechelus Reservoir portal location. After the second field reconnaissance, it was apparent that bedrock would likely be present at tunnel depth at either portal location. **Therefore, since it is 400 feet shorter with a more direct connection to the Keechelus Reservoir outlet, the T1 route was favored over the T2 route.**

7.5 Tunnel Alternative T3

This option reduces the length of the Yakima River reach that would achieve improved flows for fish habitat as a result of the K-to-K Conveyance project. However, the remaining 8.8 miles of Yakima River between the Crystal Springs Campground and Lake Easton would still receive the desired habitat benefits. It is still to be determined if this river diversion is hydraulically feasible and/or if it would lead to potentially unacceptable operational restrictions to protect fish habitat in this reach of the Yakima River.

Figure 7-1 shows an aerial view of the preliminary concept for the Yakima River diversion at the Crystal Springs Campground.

This alternative would provide several benefits:

- The tunnel route is 10 percent shorter (2,000 feet) than the route for Alternative T1.
- It would not require a new intake structure within Keechelus Reservoir.
- It would not require a new pipe or tunnel under Keechelus Dam.

- The retrieval portal at the Crystal Springs Campground would be about 65-feet shallower (about 100-feet-deep) versus the portal at Keechelus Dam.
- It would provide better access to the site from the I-90 Exit 62 interchange.

After discussion with the team and Reclamation staff, it was decided that further evaluation of the fisheries and environmental impacts, along with the hydraulic feasibility of the proposed river diversion would be required to determine if this alternative could be advanced.

Another key issue for this alternative route is to determine if the tunnel could be constructed entirely within suitable rock. The surface geologic mapping (see Section 11.0) shows that much of the route is overlain with either alluvium or alpine glacial deposits. The depth to rock in these areas is yet to be determined by geotechnical exploration along the tunnel route.

8.0 Summary of Remaining Alternatives

The characteristics of the three remaining conveyance alternatives (P3, T1, and T3) carried forward for further environmental documentation and permitting review and construction cost comparisons are summarized in Table 8-1.

The preliminary routes for the remaining conveyance alternatives are shown on Figure 8-1. Figure 8-2 shows an approximate profile of Alternative P3. Figure 8-3 and Figure 8-4 show approximate profiles of Alternatives T1 and T3 respectively.

Table 8-1. Summary of Remaining Alternatives

Alternative Characteristic	Pipeline Alternative P3	Tunnel Alternative T1	Tunnel Alternative T3
Intake Configuration	New Keechelus Reservoir tower outlet structure with fish screens and sluice gates at the north end of Keechelus Dam with the ability to draw the lake down to El. 2445		Crystal Springs Campground retractable crest diversion and fish screen intake
Keechelus Outlet Pipeline and Tunnel Length and Diameter	1,500 feet of 96-inch	1,900 feet of 96-inch	NA
Pipeline Length and Diameter	29,000 feet of 96- to 84-inch	NA	150 feet of 96-inch
Tunnel Length and Diameter	NA, but approx 300 feet of pipeline may be a trenchless crossing of I-90	19,700 feet of 10- to 12-foot-diameter TBM or horse-shoe-shaped mined tunnel	17,700 feet of 10- to 12-foot-diameter TBM or horseshoe-shaped mined tunnel
Keechelus Portal Depth	NA, but will require deep cut or trenchless construction to get below El. 2445 downslope of the dam	Approximately 165 feet for a free-flow tunnel (not pressurized)	Approximately 100 feet (at the campground)
Keechelus Portal Diameter	NA	Between 20 and 30 feet	
Kachess Portal Depth (ft)	NA	At grade	
Kachess Discharge Configuration	Pipeline discharge through control valves to a plunge pool with energy dissipating spillway to Kachess Reservoir	Approximately 440-foot-long combination of gravity-flow double box culvert, baffled spillway, concrete apron, and riprap into Kachess Reservoir	

9.0 Environmental Documentation and Permitting

9.1 Introduction and Purpose

This section compares the environmental documentation and permitting that would be required for the three K-to-K Conveyance Alternatives P3, T1, and T3. It also lists the basic environmental studies that would be needed to support the permits and documentation. The purpose of this analysis is to identify potential "fatal flaws" or excessive costs or risks associated with the proposed alternatives.

9.2 Alternative P3

Pipeline Alternative P3 would cause the most impacts and have the most permitting requirements because of the extensive land disturbance along the approximately 5-mile pipeline route. The pipeline would disturb vegetation and wildlife in areas considered sensitive by the USFS and would cross several streams and wetlands along the route. These impacts would require potentially lengthy permitting, including an individual Section 404 permit for stream and wetland impacts, and would require costly mitigation. Construction of the pipeline would disturb residents along Lake Kachess Road and those trying to access properties adjacent to Kachess Reservoir. Access to private property and the Forest Service campground at Kachess Reservoir would be restricted by pipeline construction next to Kachess Lake Road. Temporary and/or permanent property easements would be required along much of the pipeline route. The USFS expressed concerns about surficial environmental impacts along the proposed pipeline route from Lake Keechelus to the I-90 pipeline crossing. These are potential fatal flaws for this pipeline alternative.

9.3 Alternatives T1 and T3

Compared with pipeline alternative P3, both of the tunnel alternatives would reduce impacts to vegetation, wildlife, and water bodies and would generally require less extensive permitting and mitigation. Ground disturbance and related impacts would be limited to the portal areas and outlet to Kachess Reservoir. Although the tunnel portal sites would occupy significant localized land areas, the portals could be sited to avoid sensitive areas to the extent possible. The tunnel alternatives would cause fewer disruptions to residents and would require few property easements or acquisitions. During tunnel construction a temporary realignment of a short segment of Kachess Lake Road would be needed to keep the road open around the tunnel mining portal.

Tunnel Alternative T3 includes a new diversion from the Yakima River and alterations to the river and its bank to accommodate the diversion. The T3 alternative would, therefore, require a higher level of permitting and more mitigation than Alternative T1. In addition, the T3 alternative would decrease the length of the Yakima River that would benefit from reducing the artificially high summer flows. Approximately 8.8 miles of the Yakima River would benefit from improved flow conditions under Alternative T3, compared with 10.3 miles under Alternative T1.

9.4 Environmental Studies

A number of environmental studies would be required to support environmental documentation and permitting. These include field studies for wetland and stream delineations; and fish, wildlife, vegetation, and cultural resource surveys. These studies would be required for all three alternatives. The level of effort would vary depending on the amount of ground disturbance. Database studies would be required to determine the presence of endangered and threatened species as well as known historic or archaeological resources. Studies would be needed to determine if there are any mineral rights or mining claims along the pipeline or tunnel routes.

Table 9-1 summarizes the environmental studies and permitting requirements for each of the three alternatives. The table includes only the critical path environmental documentation and permitting requirements. Additional permit requirements would be identified when construction details are known, such as locations of haul routes, power lines, staging areas and spoils disposal.

Although the list of environmental documentation and permits required for the three alternatives options appears similar, it is expected that acquiring those permits for the pipeline alternative would take longer, cost more, and require more mitigation than for the tunnel alternatives. Similarly Tunnel Alternative T3 would require a higher level of permitting and more mitigation than Tunnel Alternative T1.

Table 9-1. Comparison of Environmental Documentation and Permitting Requirements

ALTERNATIVE	PIPELINE ALTERNATIVE P3	TUNNEL ALTERNATIVE T1	TUNNEL ALTERNATIVE T3
NEPA/SEPA Review	EIS with field work along entire pipeline route. Impacts to streams, wetlands, wildlife. Costly mitigation.	EIS with field work focused on portal areas at Keechelus dam and Kachess.	EIS with field work at portals at Crystal Springs Campground and Kachess.
Section 7 Consultation (Endangered Species Act)	Biological Assessment likely, with formal consultation.	Biological Assessment likely, with formal consultation.	Biological Assessment likely, with formal consultation.
Section 106 Review and Consultation (National Historic Preservation Act)	Cultural resources report requiring field surveys along entire pipeline route. Consultation with affected Tribes.	Cultural resources report requiring field surveys at portal areas. Consultation with affected Tribes.	Cultural resources report requiring field surveys at portal areas. Consultation with affected Tribes.
Forest Service Special Use Permit	Forest Service has expressed concerns about land route.	Reduces Forest Service land area involved.	Reduces Forest Service land area involved.
Corps Permits Section 404 (Clean Water Act)	Several stream crossings and possible wetlands along the pipeline route would require Section 404 permit. Section 404 permit would likely be an individual permit rather than a Nationwide permit. Mitigation requirements would be costly.	Potential wetlands at portal locations may trigger Section 404 permits. Section 404 permit could be an individual permit, but there would be less mitigation measures than for pipeline.	Diversion of the Yakima River and stream alterations as well as potential wetlands at the portal locations would trigger Section 404 and Section 10 permits. Possible costly mitigation for stream alterations.
Section 401 Permit (Clean Water Act)	Stream crossings and possible wetlands along the pipeline route would require Section 401 permit.	Project is less likely to trigger Section 401 permit.	River and stream alterations as well as potential wetlands at the portal locations would trigger Section 401 permit.
Hydraulic Project Approval (HPA)	Required for individual stream crossings along pipeline route.	May not be required if portals avoid stream impacts.	Required for diversion of the Yakima River and stream alterations at Crystal Springs Campground.
Kittitas County Shoreline Management Program*	Yakima River and Keechelus and Kachess reservoirs are shorelines of the state. Development within 200 feet of the water bodies could require a shoreline substantial development permit.	Yakima River and Keechelus and Kachess reservoirs are shorelines of the state. Development within 200 feet of the water bodies could require a shoreline substantial development permit.	Yakima River and Keechelus and Kachess reservoirs are shorelines of the state. Development within 200 feet of the water bodies could require a shoreline substantial development permit.
Kittitas County Critical Areas Review*	Potentially required for wetlands, streams and habitats along pipeline route and outfall.	Potentially required for Kachess portal and spillway.	Potentially required for Crystal Springs and Kachess portals and Kachess outlet spillway.
Ecology Dam Safety Permit	Required for tunnel under or pipeline through and alterations to Keechelus Dam.	Required for tunnel under or pipeline through and alterations to Keechelus Dam.	May be required for new Yakima River diversion dam.

*Reclamation and Ecology would coordinate with Kittitas County to determine what local permits are applicable.

10.0 Real Estate

10.1 Parcel Information

The Kittitas County Assessor's web site was used to determine the number of parcels that would be affected by each alignment. Figure 10-1 shows the alternative pipeline and tunnel alignments on a parcel map.

10.2 Pipeline Alternative P3

The pipeline Alternative P3 aligned along Kachess Lake Road would have the most significant real estate easement needs.

The Kittitas County Assessor's web site was used to determine the number of parcels that would be affected by the K-to-K pipeline alignment and number of easements needed for the project. Data was compiled using GIS tools on the website and by reviewing County parcel maps. Data was then collected for each parcel along the route and combined with parcels from surrounding property not on the route.

It was assumed that parcels where the pipeline crosses open space would need a 50-foot permanent easement and a 100-foot temporary construction easement, while parcels that run parallel with Kachess Lake Road would need a 25-foot temporary easement on each side of the road. Permanent easements would be required from the USFS, Kittitas County, WSDOT, and at least one private property owner.

The conceptual pipeline alignment would require temporary easements for approximately 64 parcels with 39 separate land owners. Forty-six of those parcels are owned by private landowners, eight by the Kittitas Conservation Trust, six by the Wenatchee National Forest, and four by the federal government.

10.3 Tunnel Alternatives T1 and T3

It is expected that the tunnel alternatives would have significantly fewer real estate easement issues than the pipeline alternative. The tunnel alternatives would primarily cross under USFS and Cascade Land Conservancy parcels. All of the surface features and construction access for both tunnel alternatives would be located on federal lands.

Alternative T1 would also cross the corner of one large undeveloped Plum Creek Timber parcel. Alternative T3 would cross under an undeveloped area of one private parcel near I-90 and three small private parcels near Kachess Reservoir.

11.0 Area Geology

The general project area is located on the eastern side of the Cascade Range, within the Cascade Volcanic Belt, close to the boundary between the northern and middle Cascades.

Figure 11-1 shows the alternative tunnel alignments and surficial geology mapping of the local project area taken from the larger USGS 1:100,000 scale geologic map (Tabor *et al.* 2000).

Based on the USGS geologic map, much of the tunnel alignments would pass through the basalt member of the Naches Formation. Sedimentary rock and rhyolite would likely be encountered at the eastern and western ends, respectively. Because the formation is highly deformed by tectonism, there are likely to be shear zones throughout the mountain, particularly at the contacts between the members and along weak layers, such as coal, siltstone or shale.

As noted in the geologic report for Keechelus Dam (Bennett 2001), the northern Cascades are marked by primarily intrusive and metamorphic rocks. The Straight Creek Fault is the major northerly trending fault of the northern Cascade Range and passes through Kachess Reservoir and Yakima River valleys in the central Cascades to the south. Although it is just to the east of the tunnel/pipeline discharge to Kachess Reservoir, this fault does not cross any of the proposed alternative pipeline or tunnel routes. The middle Cascades are dominated by Mesozoic crystalline rocks and Eocene volcanic and sedimentary rocks (Cheney 1999). Cheney notes that the Eocene stratigraphy consists of Teanaway River and Manastash River blocks on the east side of the Straight Creek Fault and the Green River-Cabin Creek block on the west. The Yakima River Valley, which is traversed in this area by Interstate 90, separates the Teanaway River block on the northeast from the Manastash River block on the southwest.

An article about the construction of Keechelus Dam (Carter 1989) describes the local Keechelus Dam area geology as a variety of early Tertiary units, primarily volcanic tuffs and breccias with some interbedded sedimentary rocks. It refers to the Keechelus Ridge anticline to the northeast of the dam. The basement rock to the northeast of the dam is pre-Tertiary Easton Schist primarily comprised of metamorphosed greenshist and blueschist with local interbedded phyllite. It is overlain by the Eocene Naches Formation consisting primarily of rhyolite, andesite and basaltic flows, tuffs, and breccias with interbedded sandstone, siltstone, shale, conglomerate, and some coal seams. The exposed rocks along the north side of the spillway channel are described as rhyolite and andesite.

A Keechelus Dam geotechnical report (Bennett 2001) describes and presents the field data obtained for the design of Keechelus Dam modifications. Exposed bedrock along the right spillway wall in the proposed Keechelus portal area is described as Tertiary Rhyolite (Tr) that is hard, slightly jointed, and slightly to moderately weathered. The report described the glacial moraines downstream of Keechelus dam as Quaternary Till composed of till on top and underlain by outwash deposits (Qow). The till is generally a mixture of moderately to very dense boulders, cobbles, gravel, sand, and fines. Outwash is the same coarse material but without the fine grained particles in the interstices.

Another geotechnical data report (Taylor 2012) provides additional information regarding geotechnical field subsurface investigations completed along I-90 between September 2011 and July 2012. Data collected from these field investigations (Bennett 2001; Taylor 2012) are generally consistent with the regional geology summarized in this section.

All of this background geotechnical information provides a preliminary indication that tunneling conditions may be quite variable along either alignment. The tunnel excavation will likely encounter competent, but jointed rock, but these conditions could also be interrupted by undesirable layers or zones of difficult tunneling conditions when encountering coal, shale, sheared rock, breccia, pumice or other volcaniclastic rocks.

12.0 Tunnel Facilities Descriptions

12.1 Keechelus Reservoir Outlet Conveyance for Alternative T1

Tunnel Alternative T1 would include a new screened outlet in Keechelus Reservoir and conveyance to the tunnel shaft and portal near the left abutment at the north end of the dam near the spillway and I-90 (Figure 12-1). As discussed in Section 2, this new outlet and conveyance would be capable of accepting and sending flow to the K-to-K tunnel for Keechelus Reservoir water surface elevations down to El. 2445.

Figures 12-2 and 12-3 show details of the Keechelus Reservoir conveyance facilities described in the following subsections.

12.1.1 Keechelus Reservoir Outlet and Fish Screens

Although there are no fish screens on the existing Keechelus Reservoir tower outlet, it is likely that fish screens would be required on the proposed K-to-K outlet structure. The conceptual design for the fish screens consists of four 9-foot-diameter 32-foot-long stainless steel cylindrical T-screens connected to and supported by two fixed steel towers. To comply with Washington Department of Fish and Wildlife (WDFW) and National Marine Fisheries Service (NMFS) criteria, the total screen area would be 2,600 square feet resulting in a 0.19 feet-per-second (fps) approach velocity at a maximum withdrawal rate of 500 cfs.

To induce a sweeping velocity, water jets would be installed along each of the cylinder screens at an angle. This angled flow across the screens assists in creating a sweeping flow in lake water conditions. This water jet system could also be used to control frazil ice during periods of operation when ice control is warranted. The T-screens would have both internal and external brushes that would clean the screens based upon one of three control modes: manual, 0.1 foot water differential, or time increments. The screen cleaning system would be powered by either electric motors or by environmentally friendly hydraulic motors that would be housed in small mechanical enclosures at the top of each steel tower structure. Other intake and screen monitoring and instrumentation and control equipment would be housed in a small building adjacent to the flow control structure.

Because of the potential for ice damage to the screens during the winter after the reservoir has been drawn down to the screen level, the support system would include vertical rails so that the T-screens could be retracted (raised) out of the water into a storage position at the end of each K-to-K diversion season.

The fish screen site would likely require a lowered lake water surface elevation and a sheet-pile cofferdam for construction of the fish screen foundation and installation of the fish screen support structure and screens. As shown in Figure 12-2, the fish screen structure site is above the lowest Keechelus Reservoir pool elevation, so in the early fall, the site could be entirely out of the water. Another option would be to drive fish screen structure support piling from a floating barge and then install the fish screen support structure and screens from the barge in shallow water.

12.1.2 Flow Isolation for Control Gate and Tunnel Inspection and Maintenance

As shown in Figure 12-3 the fish screen structures would also include four sluice gates (one at each T-screen assembly) that could be closed after raising the fish screens to isolate and dewater outlet pipeline and flow control structure; which would then allow in-the-dry maintenance and/or repairs of the outlet pipeline, tunnel, and/or flow control gates and structure. These gates could also provide redundant isolation (along with the flow control gates) of the deep tunnel for inspection and maintenance. The fish screens and sluice gates are above the low reservoir outlet elevation and could be accessed for maintenance when the reservoir is at or near the low pool elevation. The methods for powering the screens and gates are still to be determined but could include electric or hydraulic motors and actuators.

12.1.3 Conveyance from Reservoir Outlet to Flow Control Structure

A 96-inch-diameter, 680-foot-long pipeline would convey water from the new Keechelus Reservoir outlet structure to an intermediate flow control structure shaft and tunnel portal. This conveyance section could be constructed as a cut-and-cover buried pipeline (as shown in Figure 12-2). Depending upon the lake surface elevation that can be maintained during construction, the construction activity could be in a dewatered area on the lake bed or under water, and with or without shoring and dewatering. Depending upon ground conditions, it could also potentially be constructed as a tunnel beginning from the deep tunnel shaft or from the flow control structure shaft.

The 25-foot-diameter flow control structure shaft would contain two 72-inch-square flow control gates with automated motor operators. The top of this shaft and the gate operators would be accessible via an earthfill embankment and road from the dam. A building located adjacent to the shaft would contain the instrumentation and controls for the fish screens and flow control gates. The shaft would have hatches or removable panels to facilitate any necessary future crane access to the shaft interior and flow control gates.

12.1.4 Conveyance Under Keechelus Dam

Conveyance under the dam would be a 1,180-foot-long, 96-inch-diameter tunnel that would be advanced from a partially excavated deep tunnel shaft to the flow control structure shaft. Based upon previous Reclamation geotechnical borings in this area, this tunnel would be founded in rock; however, this is yet to be confirmed by additional geotechnical borings along the alignment.

Since this tunnel will be fully pressurized from Keechelus Reservoir water surface elevation and is aligned under the dam, it is anticipated that this tunnel will need to be lined – either with concrete or steel. However, the need for lining the tunnel is yet to be confirmed and will likely depend upon the depth and quality of the rock along the alignment.

As mentioned in Section 12.1.2, a construction option would be to advance this tunnel from the deep tunnel shaft, through the flow control structure shaft, then all the way out to a fish screen structure site in the lake; where the TBM could be recovered. The fish screen site would likely require a lowered lake water surface elevation and cofferdam to recover the TBM and construct the fish screen foundation.

These pipeline and/or tunnel construction methods will be further evaluated during preliminary design and will be subject to the review and approval of the Reclamation Dam Safety Office.

12.1.5 Keechelus Dam Deep Tunnel Shaft and Portal

For the open channel flow tunnel, the differential head between Keechelus Reservoir and Kachess Reservoir would be dissipated through a shaft and plunge pool at the Keechelus tunnel portal.

The 20- to 30-foot-diameter access shaft would be approximately 165 feet deep constructed through glacial soils and bedrock. Excavation in the overburden soils may require dewatering to allow shaft construction in the dry and the initial use of a temporary lining (e.g., ring stiffened liner plate). This section of the shaft would subsequently receive a liner that would be keyed into bedrock and the shaft would then likely be advanced using confined drill-and-blast methods to the required grade. Various lining options could be considered for bedrock sections including back grouted liner plate, rock bolts and shotcrete, and a structural concrete lining.

12.2 Crystal Springs Campground Diversion and Intake for Alternative T3

For Alternative T3, the Yakima River diversion (Figure 12-4) would be located in the Crystal Springs Campground approximately 8,000 river feet downstream of the existing Keechelus Dam outlet. The river at this location is approximately at El. 2390, which is high enough elevation to flow by gravity through a tunnel to Kachess Reservoir – which is at a maximum El. 2262.

There is a natural island that divides the Yakima River flow at the site – where the left (easterly) channel could be used for the diverted flow while the right channel could be used to carry the bypass flow and allow for upstream fish passage. Geomorphology of this area is expected to be relatively stable because the river flows are controlled by releases from Keechelus Dam so that the area will not be reshaped by major flood events.

The diversion would be constructed using a retractable adjustable crest dam (bottom hinged panel crest gates) on the easterly branch of the divided Yakima River channel to form a pool so that water could be diverted into the intake structure (Figure 12-5). The maximum dam pool depth would be 7.5 feet with the dam leaf crest set at 1.5 feet above the maximum pool at El. 2394. The dam would be raised only when in use for diverting water into the intake structure and tunnel during the K-to-K flow transfer. The channel islands and gap between the islands would have to be built up or sheet-piled upstream of the dam to the end of the upstream island to contain the raised water surface and submerge the intake fish screens. The environmental and hydraulic feasibility of this approach would have to be further evaluated during predesign.

The intake structure and fish screens (Figures 12-4 and 12-5) would be located just upstream of the diversion along the left bank of the river. Eleven 3.5-foot-diameter, 17-foot-long stainless steel cylindrical T-screens would be aligned along a concrete wall. To comply with WDFW and NMFS criteria, the total fish screen area would be 1,330 square feet with an approach velocity of 0.37 fps. Sweeping velocity would be designed for a minimum of 0.8 fps with a bypass flow designed for up to 50 cfs. The bypass flow would be modulated to be 10 percent of the diversion flow using an over-gate weir.

Each T-screen assembly would connect to a 36-inch-diameter pipe through the intake structure wall which in turn would connect to one of two 72-inch diameter manifold pipes. These manifold pipes would then connect to a concrete flow control structure that would contain two 72-inch-square flow control gates. A 150-foot-long, 96-inch-diameter pipe would connect the flow control structure to the K-to-K deep tunnel shaft and portal.

The T-screens would have both an internal and external brush that would clean the cylinder screens using one of three cleaning modes: manual, 0.1 foot water differential, or time increment. The screen cleaning system would be powered by either electric motor or environmentally friendly hydraulic motors. The cylindrical T-screens would be mounted on a vertical rail system allowing each of the screen assemblies to be retracted to a raised position as necessary for maintenance, during periods when not in use, and/or to protect during flooding or icing conditions. A small building would house the mechanical support equipment and as well as the instrumentation and controls.

12.2.1 Crystal Springs Tunnel Shaft and Portal

Because this site is downstream and downslope from the dam, the tunnel portal here would only need to be about 100 feet deep, versus 165 feet deep for the Tunnel Alternative T1 portal near Keechelus Dam. The pipe from the intake structure would discharge into a tunnel portal shaft and plunge pool.

The access shaft for the Crystal Springs portal would be 20 to 30 feet in diameter and constructed through alluvium, glacial soils, and bedrock. Excavation in the overburden soils may require dewatering to allow shaft construction in the dry and the initial use of a non-temporary lining (e.g., ring stiffened liner plate). This section of the shaft would subsequently receive a liner that would be keyed into bedrock and the shaft would then be advanced using drill-and-blast methods to the required grade. Various lining options could be considered for bedrock sections including back grouted liner plate, rock bolts and shotcrete, and a structural concrete lining. Although it would not be as deep, the potential for groundwater and the depth of the alluvium overburden in the vicinity of the Yakima River may make the tunnel shaft at Crystal Springs just as challenging to construct as the deeper one at Keechelus Dam.

12.3 Tunnel Discharge at Kachess Reservoir

12.3.1 Tunnel Portal

The tunnel from either Keechelus Dam or from Crystal Springs would discharge at a portal located adjacent to Kachess Reservoir (Figure 12-6). This portal would also serve as the primary location of construction activities for boring (TBM) or mining the tunnel. This end of the tunnel was selected to be TBM launch/mining portal because it can be a “drive in” at-grade portal, it would be a positive (uphill) grade (allowing for gravity flow of drainage from the tunnel), and it would have good access to Kachess Lake Road.

12.3.2 Lake Kachess Road Temporary Realignment

Based upon the field observations, it appears that the Lake Kachess Road in the portal area could be temporarily realigned to allow for continued local vehicular access around the site during construction. Relocation of the road would also provide more room for construction activities in the Kachess Portal area.

As shown on Figure 12-6, the existing rock slope adjacent to the north side of the road would be cut back to approximately El. 2300. The excavated material would then be used to enlarge the work site by filling the area on the south side of the road and as grading material to temporarily relocate Kachess Lake Road.

Once the work area is constructed and the road relocated, the tunnel portal would be constructed using open cut drill-and-blast methods and supported using rock bolts and shotcrete. A nominal 200-foot-long starter tunnel would be constructed using drill-and-blast methods to facilitate installing the TBM and trailing gear.

Trucks would use the Lake Kachess Road to transport material excavated from the tunnel to a designated disposal area.

12.3.3 Kachess Tunnel Discharge/Drop Structure and Spillway

After the tunnel excavation and construction is completed, the portal site would be further excavated for the construction of the concrete tunnel discharge/drop structure. A profile of this structure and spillway is shown on Figure 12-7. This structure would receive the flow from the tunnel and distribute the flow to a 240-foot-long double box culvert (as shown) or parallel pipes to convey the flow under Lake Kachess Road. Flow would then continue through a concrete transition to a 90-foot-long baffled chute spillway channel then directly to a riprapped area in Kachess Reservoir. The riprap would be sized and extended to a depth as necessary to prevent erosion of the bank.

The Lake Kachess Road crossing over the outlet pipelines or channel could be constructed while the road is temporarily realigned. Once the tunnel discharge/drop structure and box culvert (or pipes) were constructed, the permanent road would be restored to its original location and reopened to traffic. The temporary road would then be used to construct the spillway transition and baffled spillway channel to the lake shoreline. The concrete channel would be extended a far as practical with a partially drawn down lake. The riprap from the end of the spillway would then be place on the lake bottom using a barge and crane.

13.0 Opinions of Probable Construction Costs

Preliminary budgetary opinions of probable construction costs (OPCCs) were prepared for each of the remaining alternatives. The pipeline cost estimate was prepared for Pipeline Alternative P1 as part of the March 2011 Technical Memorandum: *Costs of the Integrated Water Resources Management Plan* (Reclamation and Ecology 2011a). New appraisal level cost estimates were prepared for Tunnel Alternatives T1 and T3.

At this level of project definition, these OPCCs are considered to be AACE International Class 4 estimates with an expected accuracy range of minus 20 percent to plus 40 percent. These estimated construction costs do not include additional costs for project administration, permitting, engineering, geotechnical, surveying, environmental mitigation, real estate, and construction management. An allowance for those costs is included in Section 13.3.

13.1 Pipeline P3 Construction Cost

Since the majority of Pipeline Alternative P3 is similar to Alternative P1, the pipeline costs were not re-estimated for this TM but rather indexed to 2013 costs for a relative comparison to the tunnel alternatives. Table 13-1 summarizes the Pipeline Alternative P1 construction costs.

Table 13-1. Pipeline Alternative P1 Construction Costs

COST ITEM	COST
1. Materials and Labor	
Intake Screens & Connection to Existing Outlet	$1,768,000
Wye Structure & Connections to Existing	$4,446,000
Pipeline from Wye Structure to Future Outlet Control Valve Building (~25,000')	$86,373,000
Pipeline from Future Outlet Control Valve Building to STA 275+10 (~1,000')_	$958,000
Materials and Labor Subtotal	$93,546,000
2. Field Overhead and Mobilization	$2,806,000
3. Other Contract Costs (unlisted items, changes, fee, bonds/insurance)	$16,712,000
Contract Cost	$113,064,000
4. Contingencies	$28,266,000
Field Cost	$141,330,000
5. Sales Tax	$5,339,000
2010 Construction Cost (3rd Quarter 2010)	$146,669,000

[1] Reference: March 2011 *Costs of the Integrated Water Resource Management Plan Technical Memorandum*.

The above costs for Alternative P1 would likely be somewhat higher for the 3,000 feet longer Alternative P3 pipeline. Alternative P3 also would have similar costs to Alternative T1 for Keechelus Reservoir intake and fish screens.

To account for the 3,000 feet additional pipeline in Alternative P3, the Alternative P1 cost of $86.4 million for the 25,000 foot-long pipe section (of the total 26,000 feet) was increased by 12 percent to $96.8 million. The materials and labor subtotal then increases by 11 percent to $103.9 million. Applying this 11 percent increase to the remaining associated costs, contingencies, and sales tax results in a total revised 2010 construction cost of approximately $163 million for Alternative P3.

The Reclamation Construction Field Cost Index for steel pipelines for October 2010 (359) and April 2013 (382) were used to calculate a 6.4 percent cost escalation. This escalation was applied to the $163 million Alternative P3 2010 estimate resulting in an estimated Alternative P3 2013 construction cost of approximately $173 million. The Class 4 construction cost range (-20 percent to +40 percent) would be from $138 million to $242 million.

13.2 Tunnel Alternative T1 and T3 Construction Costs

Opinions of probable construction costs were prepared for Tunnel Alternatives T1 and T3 in May of 2013. The costs for these alternatives were based upon the conceptual level drawings and project descriptions contained in this report. Table 13-2 presents a summary of the rounded itemized costs for the major facilities for each alternative. With no available deep tunnel rock information, the tunnel unit costs assume that the tunnel will consist of a combination of unlined, rock-bolted, and some lined sections. The detailed cost itemization tables are included in Appendix B.

Table 13-2. Tunnel Alternatives T1 and T3 Base Estimated Costs

COST ITEM	ALTERNATIVE T1	ALTERNATIVE T3
1. Materials and Labor		
Intake and Screen Structure	$3,168,000	$2,508,000
96" Pipeline and Flow Control Structure	$2,345,000	$681,000
96" Lined Tunnel	$2,841,000	NA
12' Diameter Deep Tunnel (combination of unlined, rock-bolted, and lined tunnel sections)	$64,106,000	$57,673,000
Deep Tunnel Shaft	$2,274,000	$1,554,000
Discharge Structure and Spillway	$2,711,000	$2,711,000
Materials and Labor Subtotal	$77,445,000	$65,127,000
2. Field Overhead and Mobilization	$5,421,000	$4,559,000
3. Other Contractor Costs (unlisted items, changes, fee, bonds/insurance)	$14,277,000	$12,000,000
Contract Cost	$97,143,000	$81,686,000
4. Contingencies	$24,286,000	$20,422,000
Field Cost	$121,429,000	$102,108,000
5. Sales Tax	$922,000	$762,000
2013 Construction Cost (1st Quarter 2013)	$122,351,000	$102,870,000

13.3 Relative Construction Cost Summary Comparison

Table 13-3 presents a relative comparison of the Class 4 appraisal level ranges of estimated construction costs of the three alternatives P3, T1, and T3. The 2013 Construction Cost columns summarize the above construction costs with appropriate ranges. The 2013 Project Cost columns include an additional 30 percent allowance for project administration, overhead, permitting, engineering, geotechnical, surveying, environmental mitigation, real estate, and construction management. This associated project cost allowance was also used for the other projects presented in the Integrated Plan. The pipeline Alternative P3 2013 estimated base project cost is approximately $66 million more than Alternative T1 and $91 million more than Alternative T3.

Table 13-3. Conveyance Alternatives Ranges of Relative Costs

ALTERNATIVE	2013 Construction Cost ($ million)			2013 Project Cost ($ million)		
	Low	Base	High	Low	Base	High
Pipeline Alternative P3	$138	$173	$242	$180	$225	$315
Tunnel Alternative T1	$98	$122	$171	$127	$159	$223
Tunnel Alternative T3	$82	$103	$144	$107	$134	$188

14.0 Conclusion

Based upon a review and comparison of the engineering, environmental, and relative construction costs, the pipeline Alternative P3 will be eliminated from further consideration. The reasons for eliminating the pipeline alternative are described in the following sections.

14.1 Cost Criteria

- Based upon a relative comparison of the probable project costs – it is likely that the pipeline project cost would be approximately 40 percent more than the highest cost tunnel alternative.
- This cost difference does not include the costs for mitigation that may be needed to offset the impacts of open cut construction through USFS land, private property, and along Lake Kachess Road.

14.2 Engineering Criteria

- To maintain full pressure pipe flow, the pipeline could require higher maintenance high pressure flow control valves on the discharge end of the pipeline; whereas the tunnel alternatives have easier to maintain flow control gates at the inlet end of the gravity free-flow tunnel.
- More difficult construction logistics and truck access – because of the additional length, width, and depth of excavation, the pipeline would require approximately 70,000 cubic yards more excavation and more than 50,000 cubic yards more imported pipe zone backfill material than the tunnel alternatives.
- The pipeline would have approximately 30,000 cubic yards more excavated spoil material to be hauled off-site than the tunnel alternatives.
- A 50 foot excavated cut or tunnel would be required through a saddle at the highest point in the pipeline alignment to keep the pipeline below the hydraulic grade line under all flow conditions. Construction of this cut along or near an existing road would be very challenging and pose significant risks.
- The pipeline would require multiple exposed blow-offs (drains) and air/vacuum release valve stations that would have to be periodically inspected and maintained along the alignment.

14.3 Environmental Criteria

- Pipeline Alternative P3 would cause the most impacts and have the most permitting requirements because of the extensive land disturbance along the pipeline route.
- The pipeline would disturb vegetation and wildlife in areas considered sensitive by the USFS and would cross several streams and wetlands along the route.
- The environmental impacts would require potentially lengthy and more complex permitting, including an individual Section 404 permit for stream and wetland impacts, and would require costly mitigation.

- Construction of the pipeline would disturb residents along the Lake Kachess Road pipeline route.
- Access to private property and the USFS campground at Kachess Reservoir would be restricted by pipeline construction next to Lake Kachess Road.
- Approximately 80,000 more cubic yards of excavated spoil and imported backfill material would result in approximately 4,000 more truck trips (20 cubic yard truck capacity) – not including the additional truck trips that would be required to haul the steel pipeline to the site.
- Temporary construction and some permanent easements would be required along the length of the pipeline.
- The USFS concerns for surficial environmental impacts along the pipeline route from Lake Keechelus to the I-90 pipeline crossing as well as the public and private property impacts resulting from the open trench construction along Lake Kachess Road are potential fatal flaws for this alternative.

15.0 Next Steps

Next steps for final comparison and selection of a conveyance alternative for the K-to-K project include the following:

- Review data from the Phase 1 geologic investigations under way during 2013 and assess implications for design and cost of Alternatives T1 and T3.
- Update and confirm system operational criteria – as they relate to the flows, operational periods, and any Yakima River flow restrictions for comparing Alternatives T1 and T3.
- Refine system hydraulics based upon the updated operational criteria.
- Determine if Alterative T3 is feasible after a more detailed review of river hydraulics, environmental permitting, and fisheries issues.
- Confer with Reclamation regarding Dam Safety Office considerations with respect to the Keechelus Reservoir outlet for Alternative T1.
- Re-consult with agencies including the USFS, WSDOT, USFWS, NMFS, and others as applicable.
- Refine design concepts for intake, fish screening, intake connections, and discharge structures.
- Evaluate and compare the engineering, constructability, risks, schedule constraints, and environmental and social impacts for Alternatives T1 and T3 and assist Reclamation and Ecology to determine which alternative best meets project criteria.
- Complete a topographic survey and more detailed Phase 2 geologic investigation of the selected tunnel alignment.
- Prepare 30 percent feasibility level drawings for the selected alternative project features.

16.0 References

Bennett, D.J. (2001). *Geologic Design Data Report 2000 Field Investigations for Corrective Action Safety of Dams Programs, Keechelus Dam, Yakima Project, Washington, Volumes 1-3.* Bureau of Reclamation Regional Resource and Technical Services Geology, Exploration and Instrumentation Group, Boise, Idaho, June.

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Peterka, A.J., (1978). *Engineering Monograph No. 25 Hydraulic Design of Stilling Basins and Energy Dissipators*, A Water Resources Technical Publication by US Department of the Interior, Bureau of Reclamation, Revised January 1978.

Tabor, R.W., Frizzell Jr., V.A., Booth, D.B., and Waitt, R.B. (2000). *Geologic Map of the Snoqualmie Pass 30X60 Minute Quadrangle, Washington.* U. S. Geological Survey, Geologic Investigations Series I-2538.

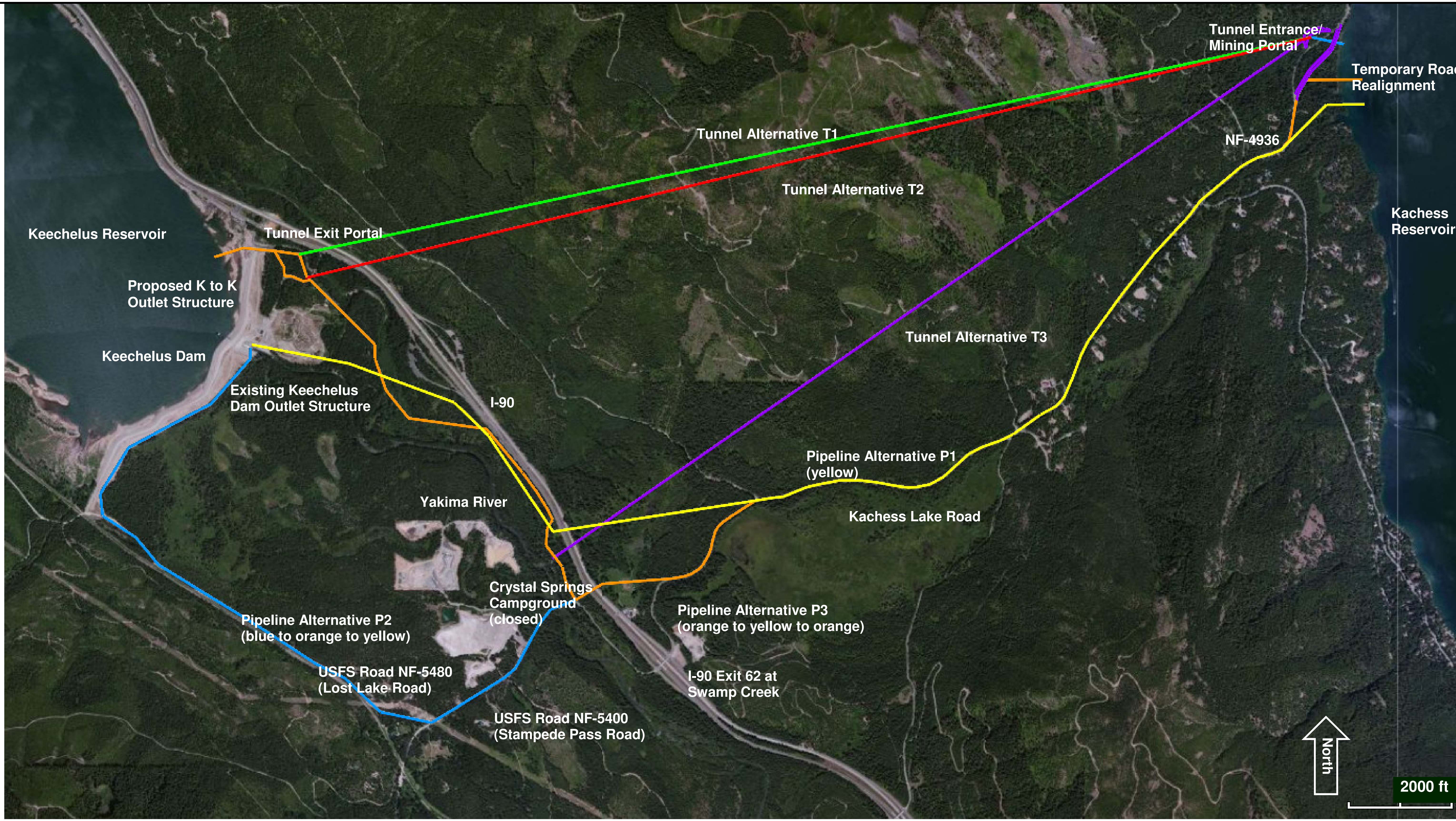
Taylor, G. L. (2012). *Geotechnical Data Report I-90/Snoqualmie Pass East – Phase 2A,* Washington State Department of Transportation, Engineering and Regional Operations, Construction Division, May.

17.0 List of Preparers

NAME	BACKGROUND	RESPONSIBILITY
HDR ENGINEERING, INC.		
Jim Peterson	Professional Engineer	Task Manager/Lead Engineer
John Nelson	Professional Engineer	Fish Screen/Intake Concepts and Costs
Richard Glassen	Construction Cost Estimator	Opinions of Probable Cost Estimates
Mike Blanchette	Professional Engineer	QC
Sri Rajah	Professional Engineer	Engineer/QC
Bob King	Professional Engineer	QC
Andrew Graham	Water Resource Planner	Project Manager/QC
ANCHOR QEA		
Adam Hill	Professional Engineer	Hydrologic Criteria and GIS
SUBTERRA		
Chris Breeds	Professional Engineer	Tunneling Engineer/QC
SHANNON AND WILSON		
Bill Laprade	Geologist	Area Geology Characterization

Appendix A

Figures



HDR

Figure 3-1

Keechelus-to-Kachess Conveyance Alternatives

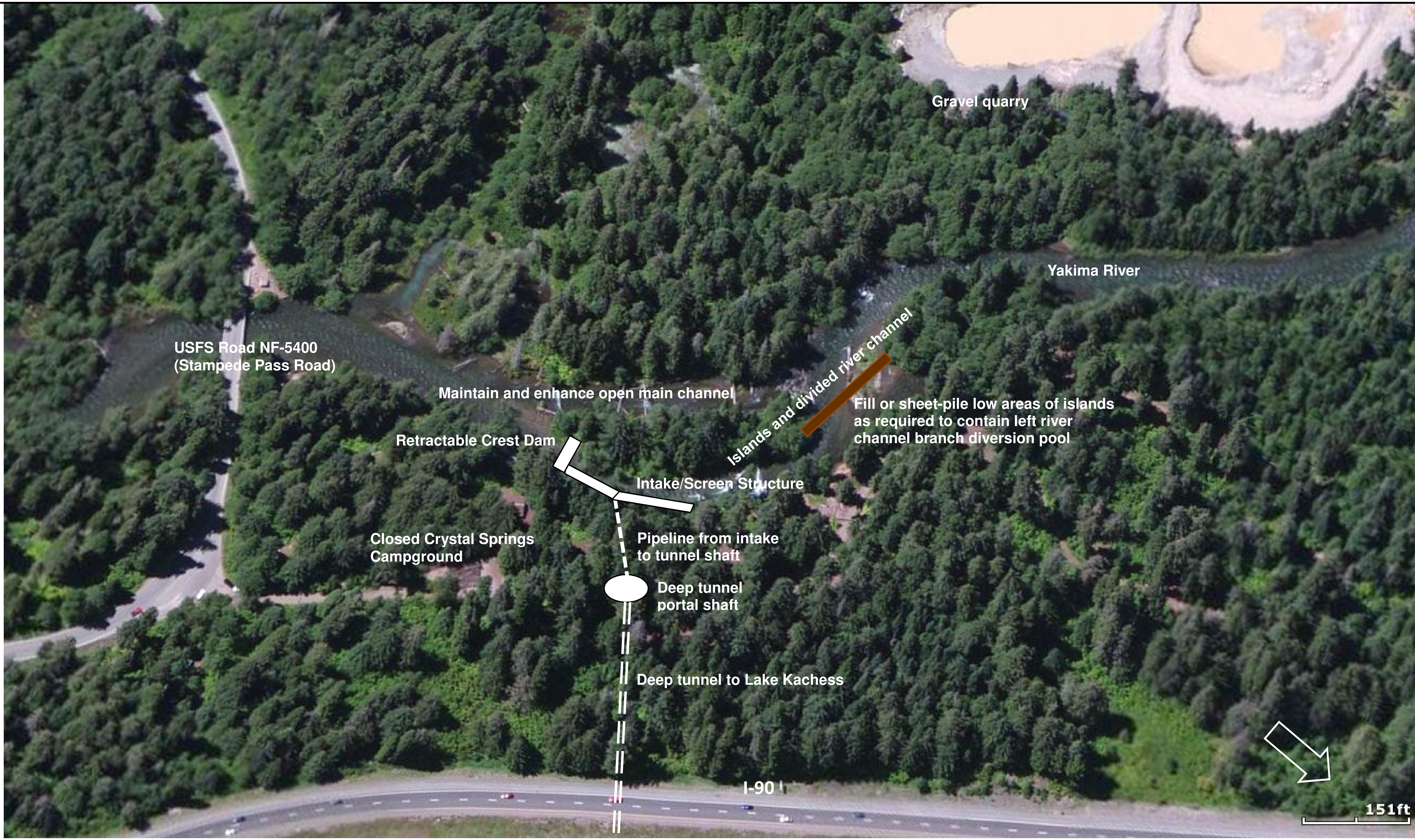


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Figure 7-1
Tunnel Alternative T3
Crystal Springs Campground Diversion Concept

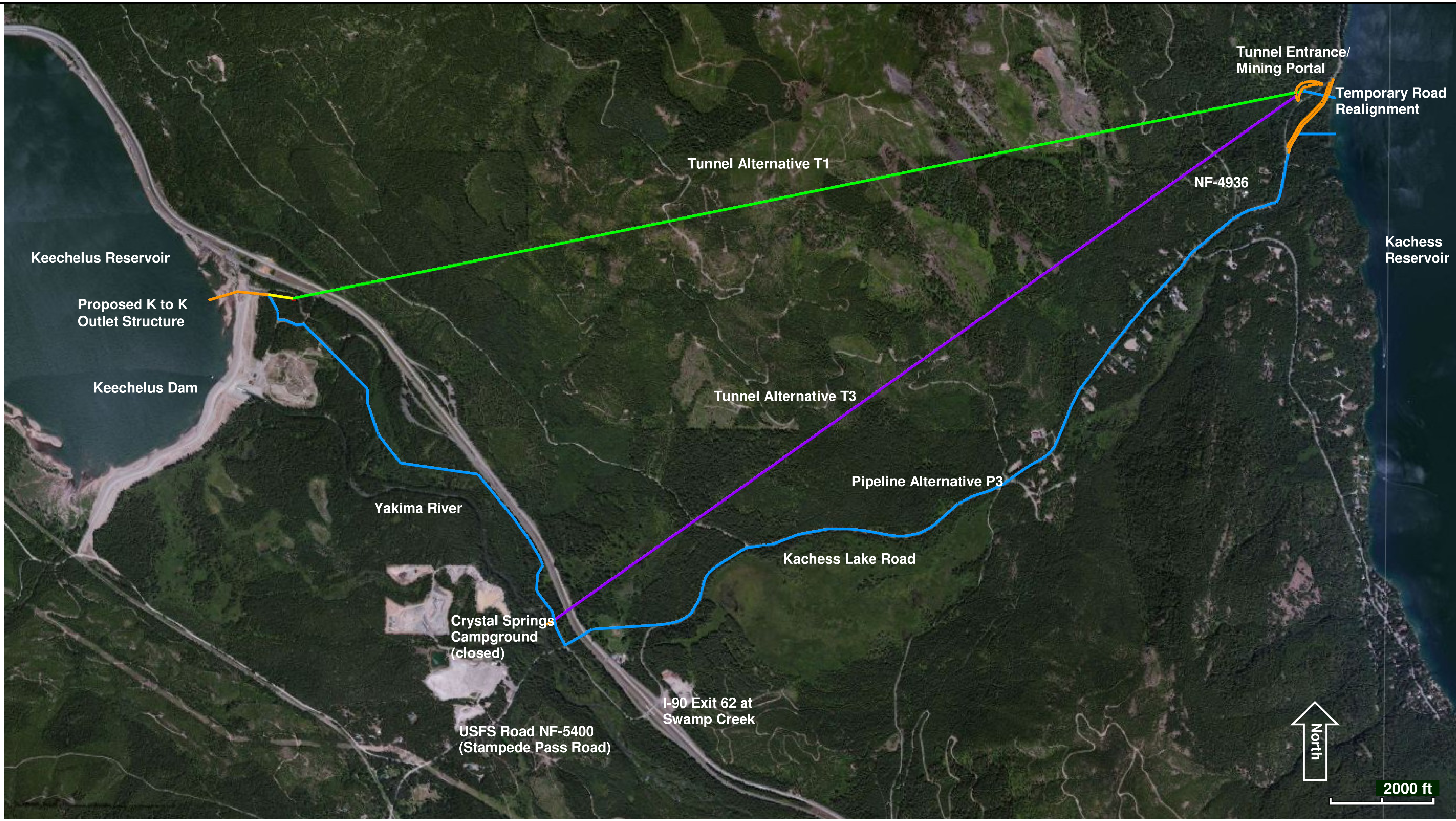

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Figure 8-1

Remaining K-to-K Conveyance Alternatives

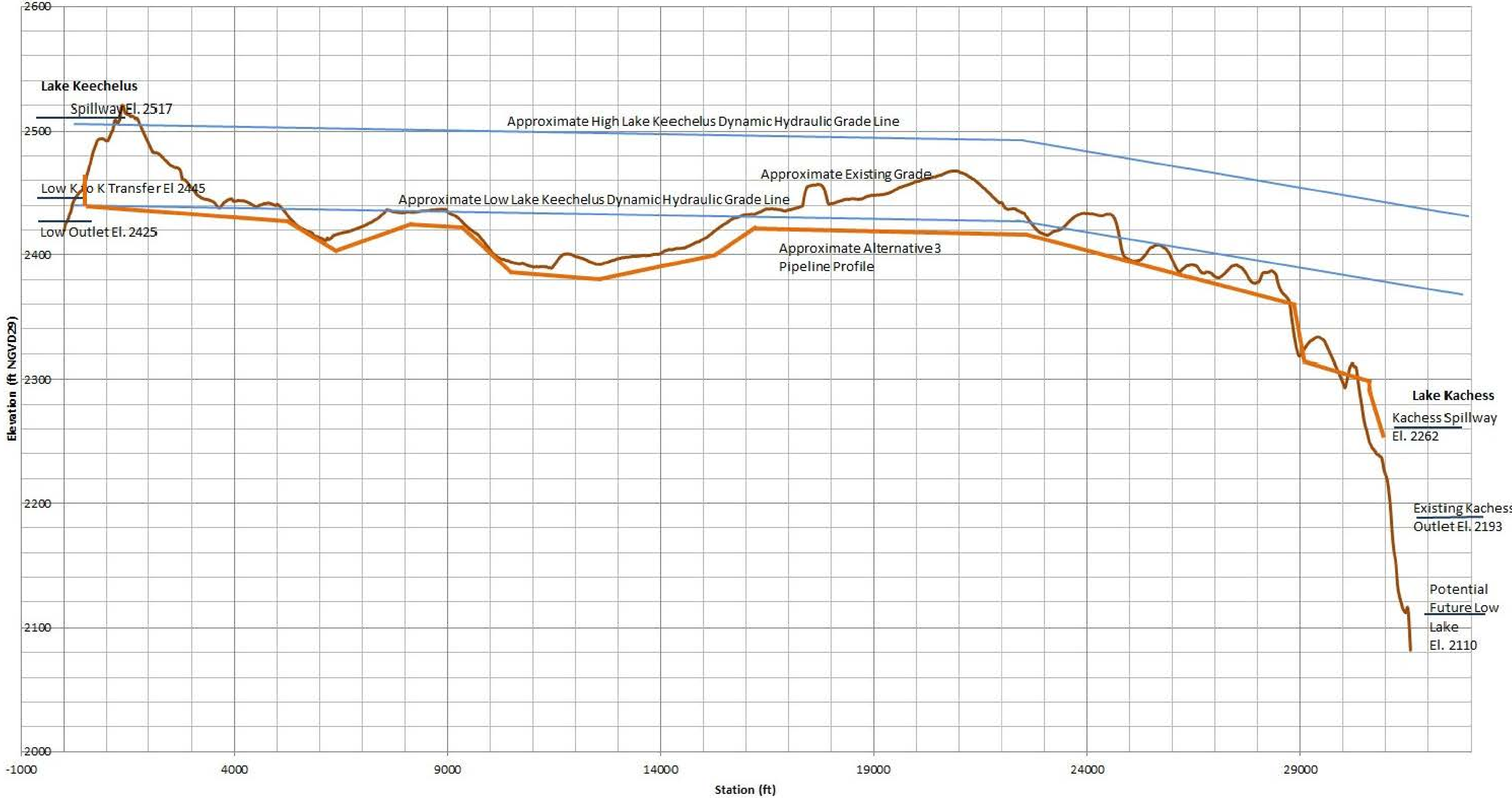

Figure 8-2
K-to-K Conveyance
Pipeline Alternative P3 Profile

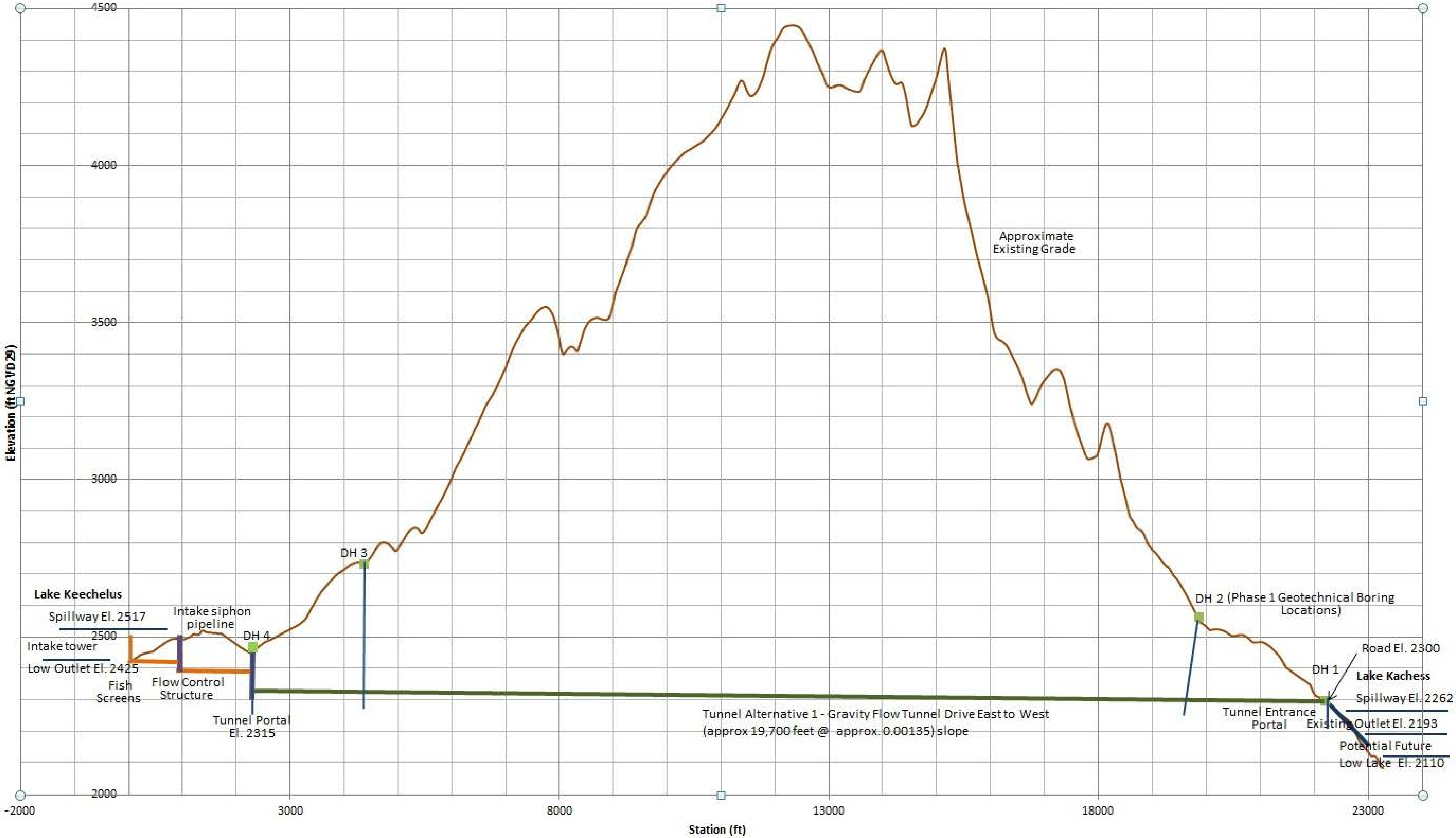

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Figure 8-3
K-to-K Conveyance
Tunnel Alternative T1 Profile

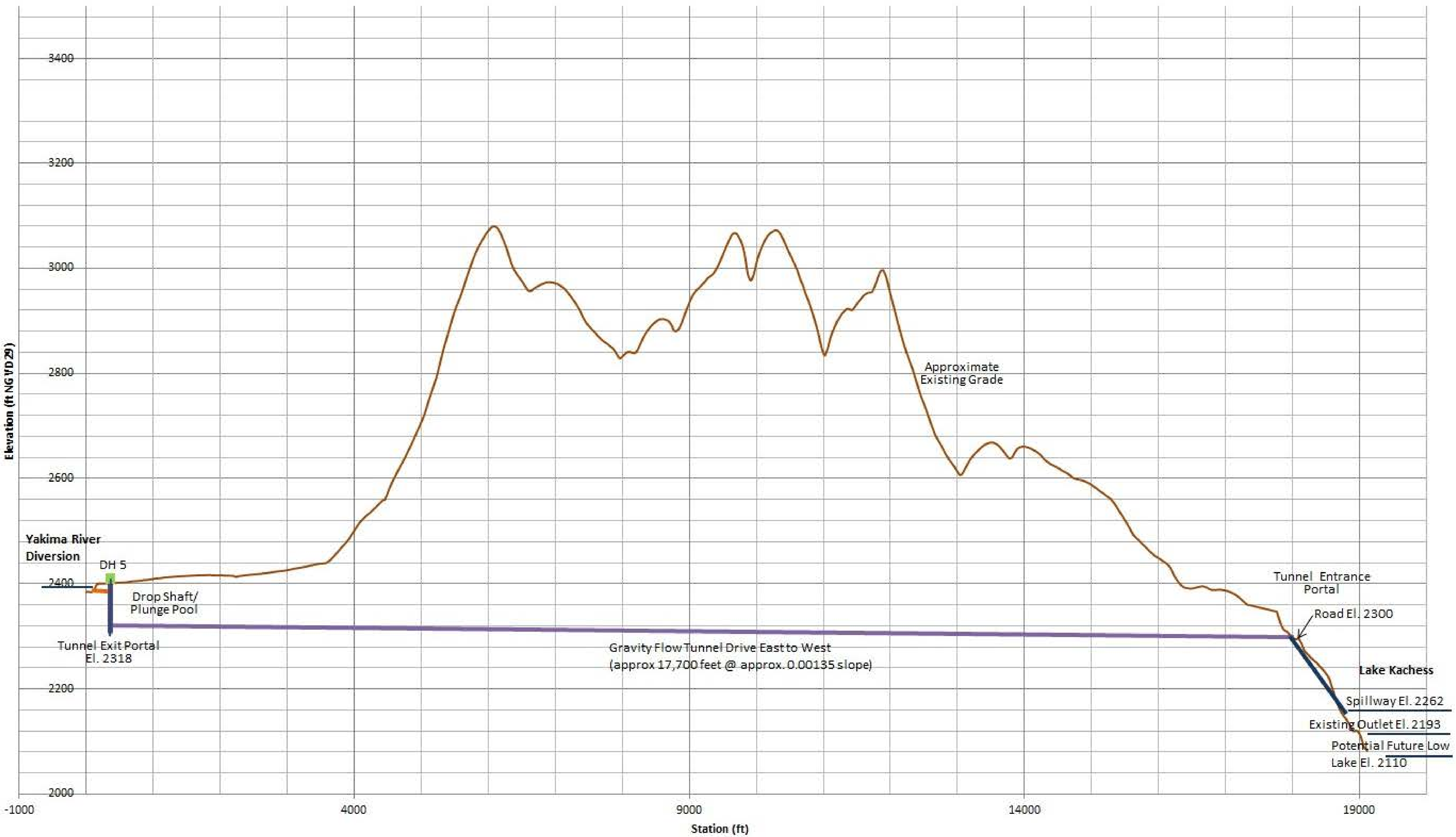
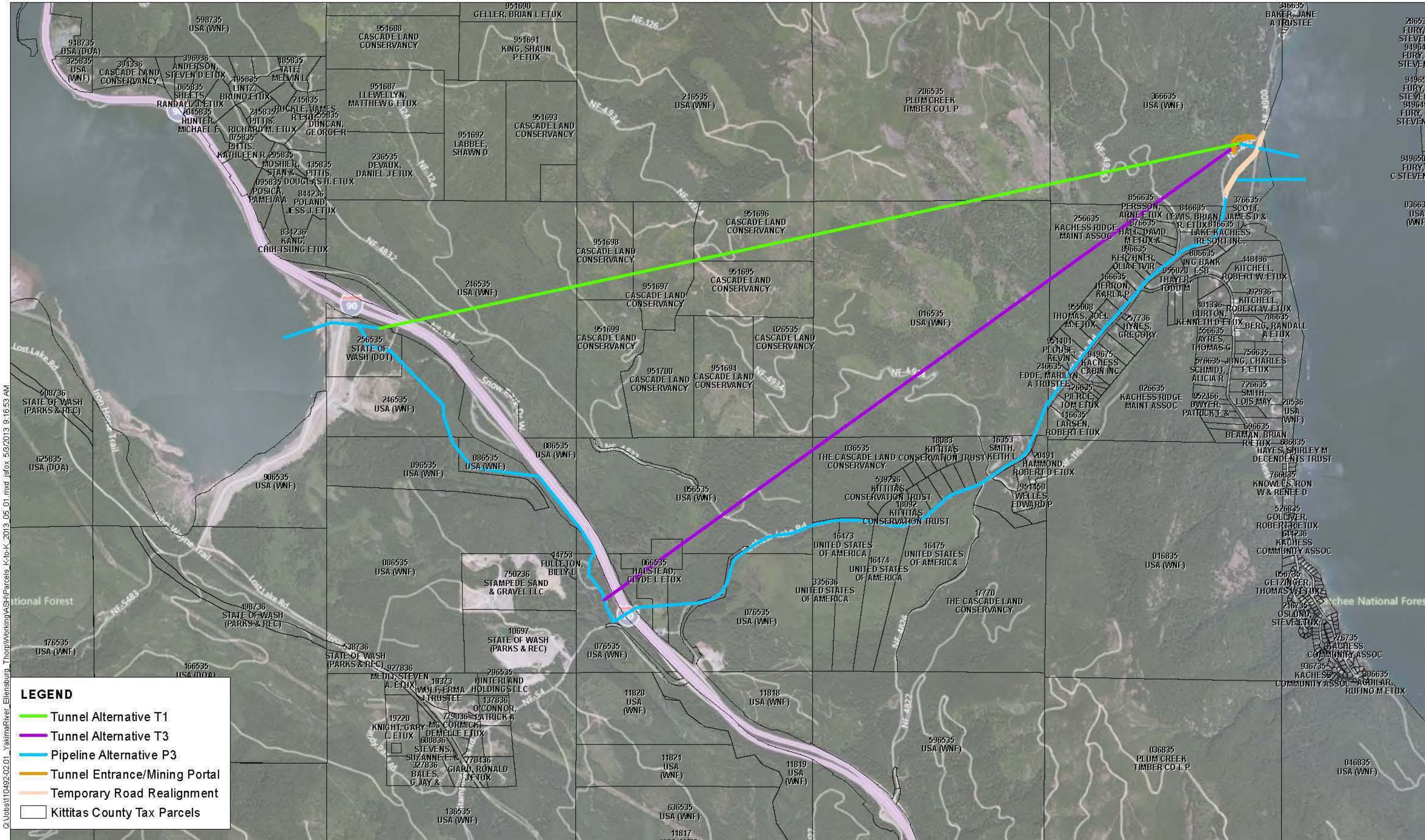


Figure 8-4
K-to-K Conveyance
Tunnel Alternative T3 Profile



Q:\Jobs\10492-02-01_YakimaRiver_Ellensburg_Thorp\Working\ASH\Parcels K-to-K_2013_05_01.mxd jsfox 5/3/2013 9:16:53 AM

NOTES:
1. Parcel boundaries are from Kittitas County GIS. Kittitas County has indicated that parcel boundaries are off by as much as 100 feet in rural areas.

Feet
0 1,500 3,000 4,500 6,000

Property Ownership
Figure 10-1

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K-to-K Conveyance Alternatives

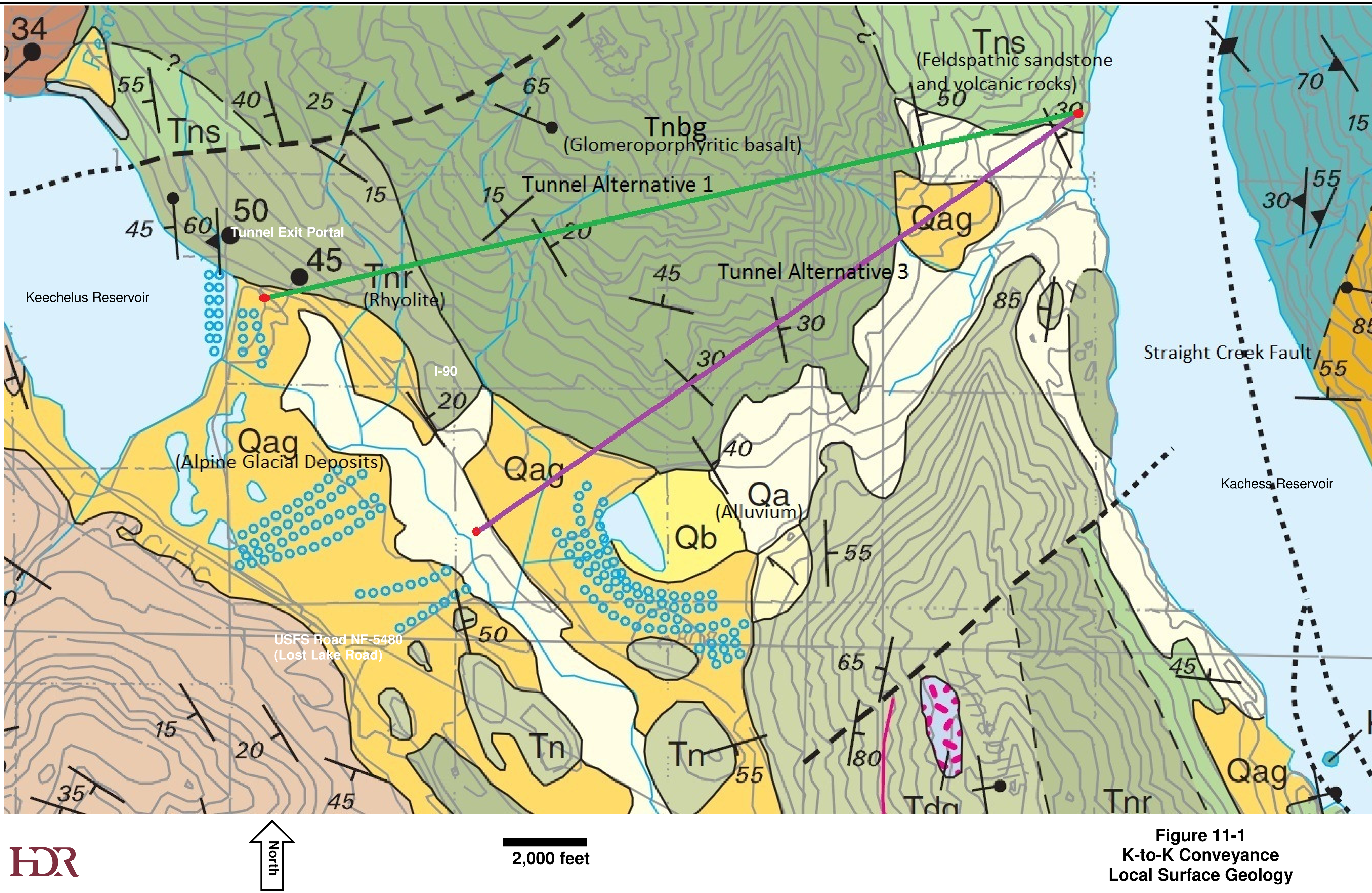
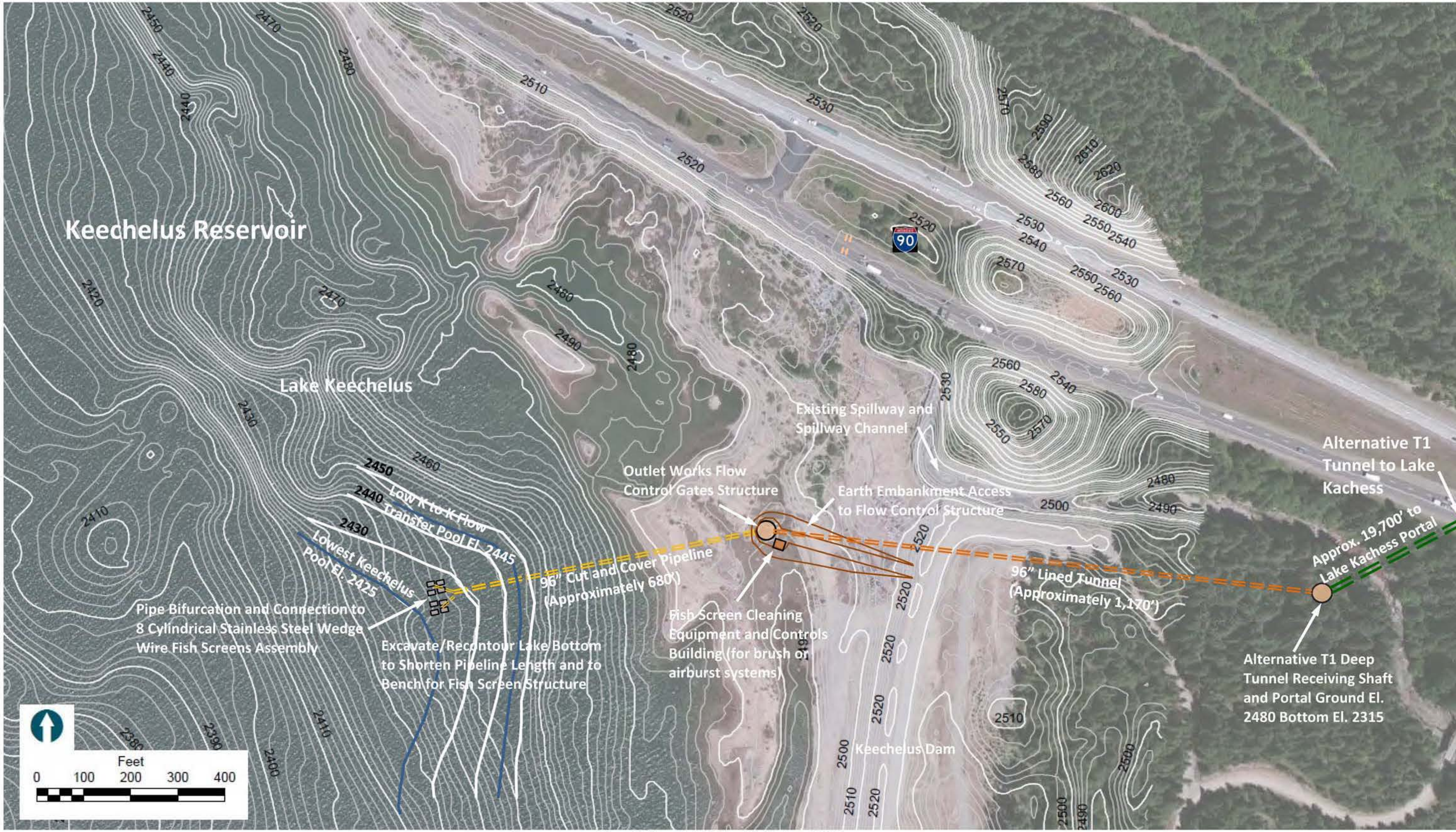


Figure 11-1
K-to-K Conveyance
Local Surface Geology



Contours created from Yakima Field Office LiDAR data (2000) and Yakima Field Office lake bathymetry data converted from NAVD88 to NGVD29 (assumed vertical change = -1.2 meters).

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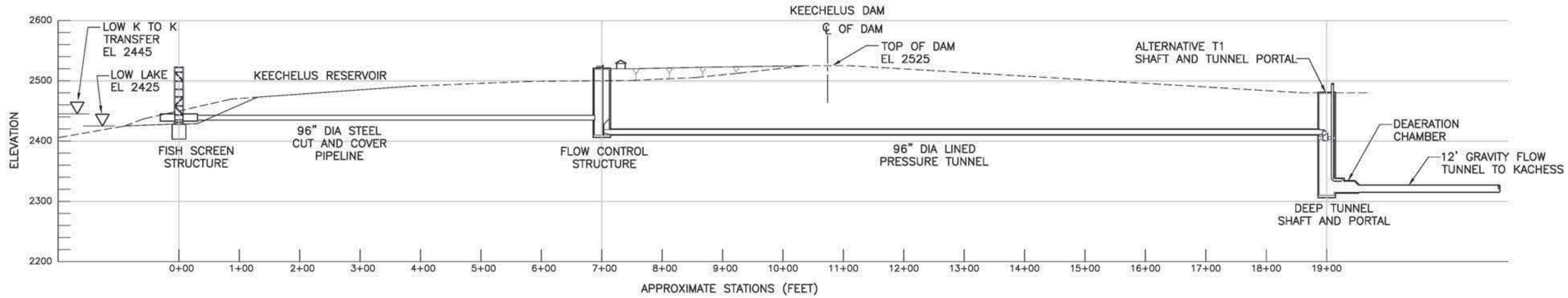
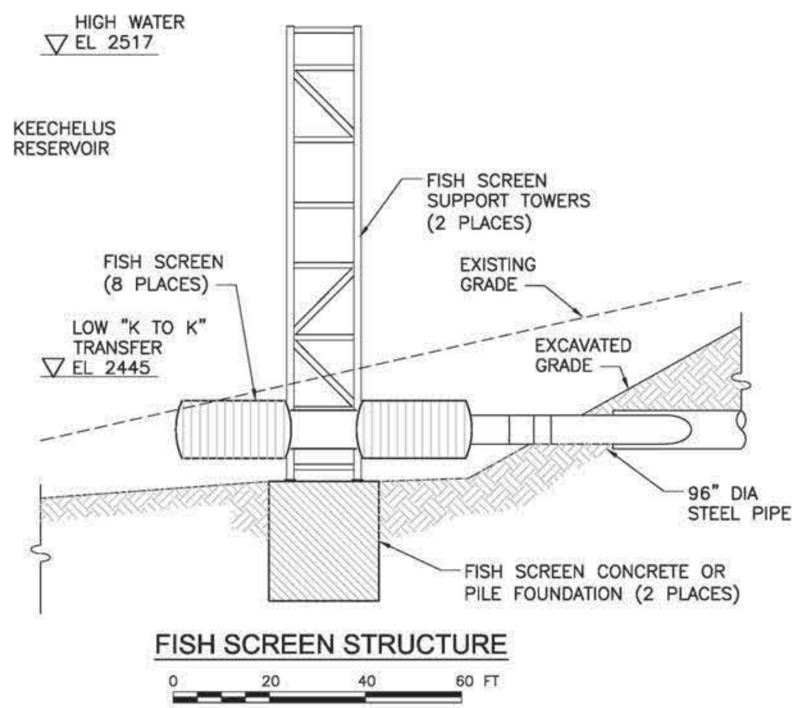
Figure 12-1

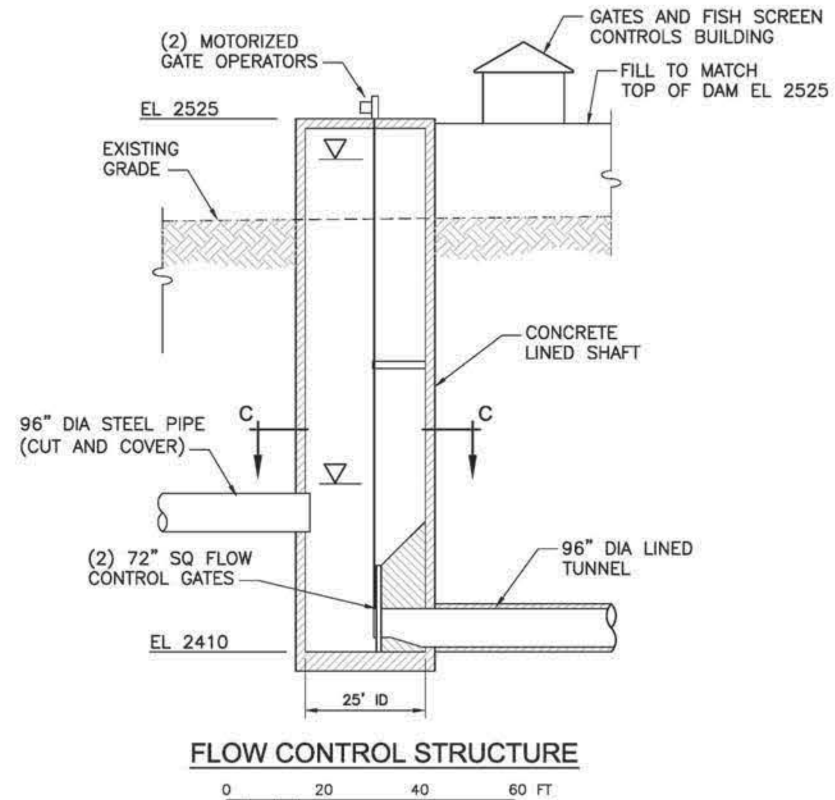
K-to-K Tunnel Alternative T1 - Lake Keechelus Receiving Shaft Connector Pipeline/Tunnel and Fish Screens Site Plan



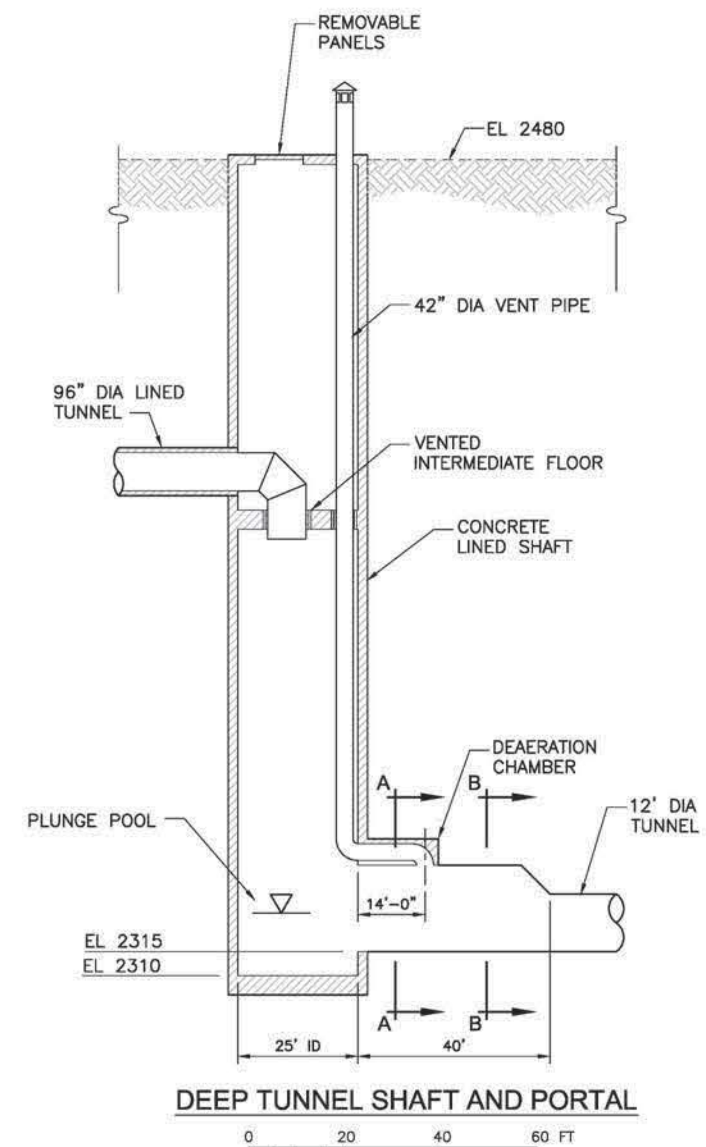
PIPELINE AND TUNNEL PROFILE
SCALE AS NOTED



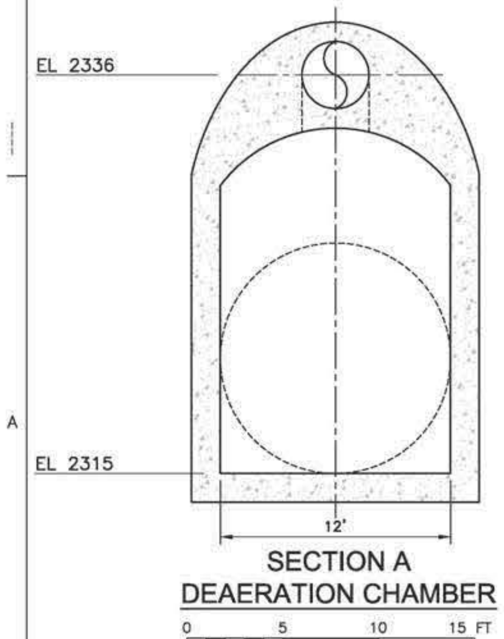
FISH SCREEN STRUCTURE



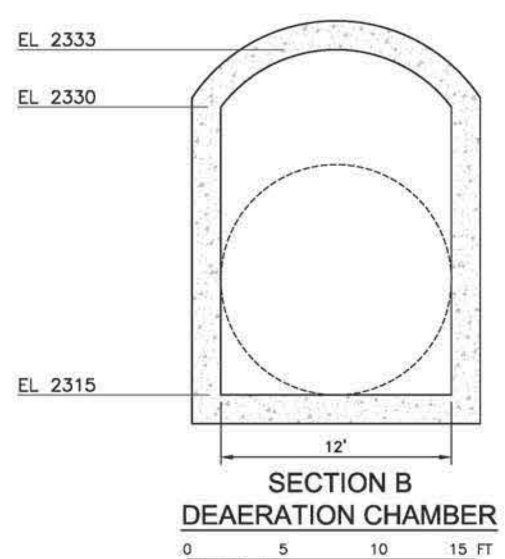
FLOW CONTROL STRUCTURE



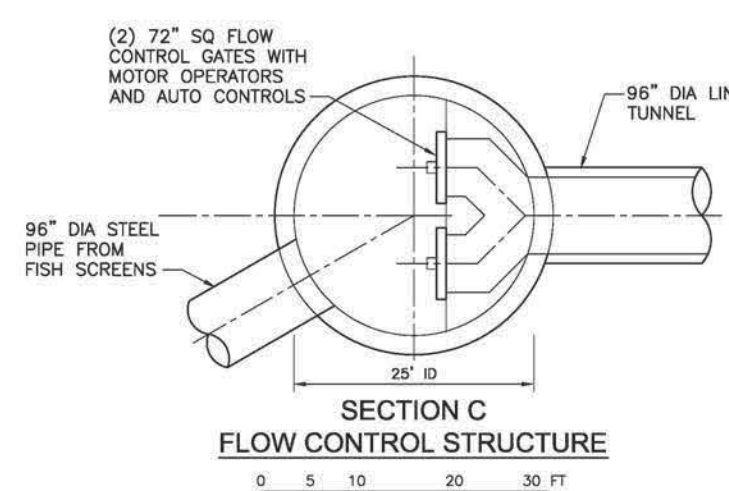
DEEP TUNNEL SHAFT AND PORTAL



SECTION A
DEAERATION CHAMBER



SECTION B
DEAERATION CHAMBER



SECTION C
FLOW CONTROL STRUCTURE

PRELIMINARY CONCEPT DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN WRFS PLAN

K-TO-K CONVEYANCE TUNNEL ALTERNATIVE 1
KEECHELUS RESERVOIR OUTLET
PROFILE, SECTIONS AND DETAILS

DESIGNED JP
DRAWN AB
CHECKED JN
TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE
BOISE, ID 04.29.2013

FIGURE 12–2

SHEET OF

September 12, 2013
AutoCAD Rel. 17.1s

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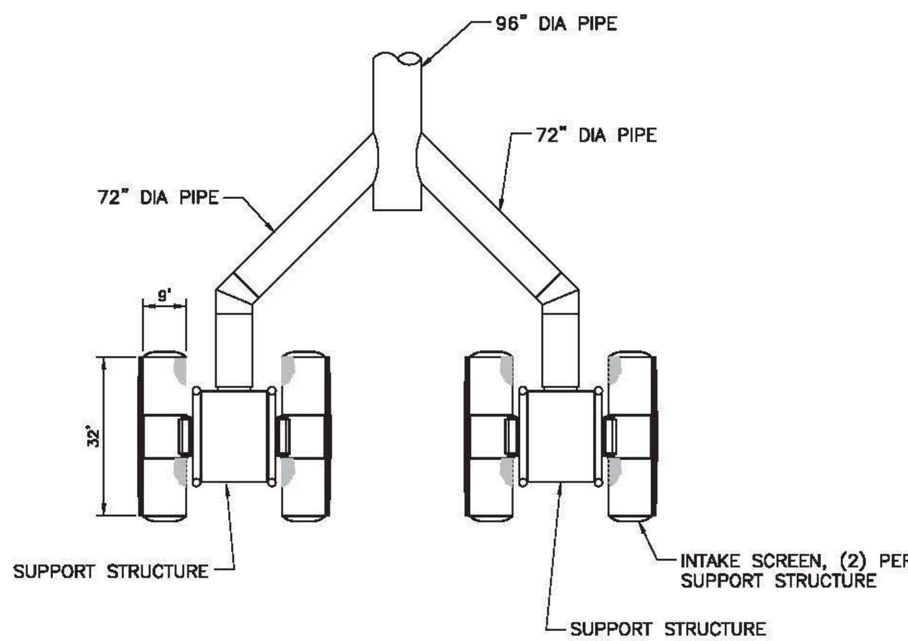
Managing Water in the West

HDR



FISH SCREEN STRUCTURE PLAN

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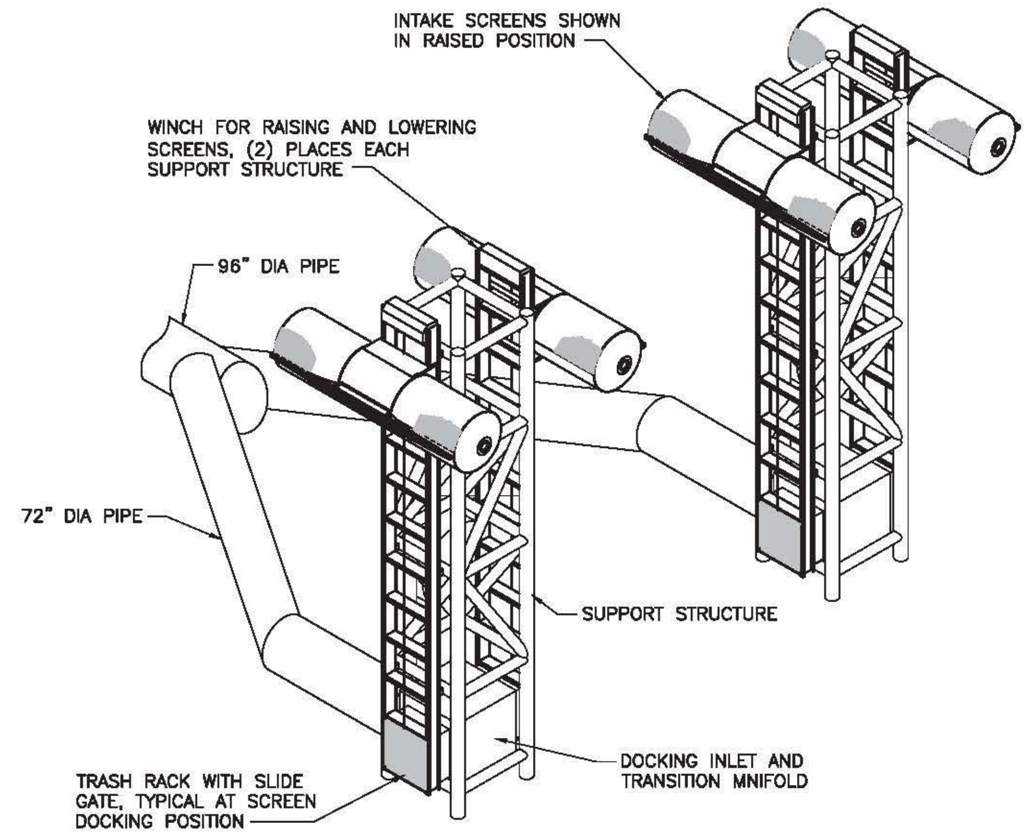


FISH SCREEN STRUCTURE ISOMETRIC

NOT TO SCALE

ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN IWRS PLAN

K-TO-K CONVEYANCE TUNNEL ALTERNATIVE 1
KEECHELUS RESERVOIR OUTLET
FISH SCREEN STRUCTURE PLAN AND ISOMETRIC

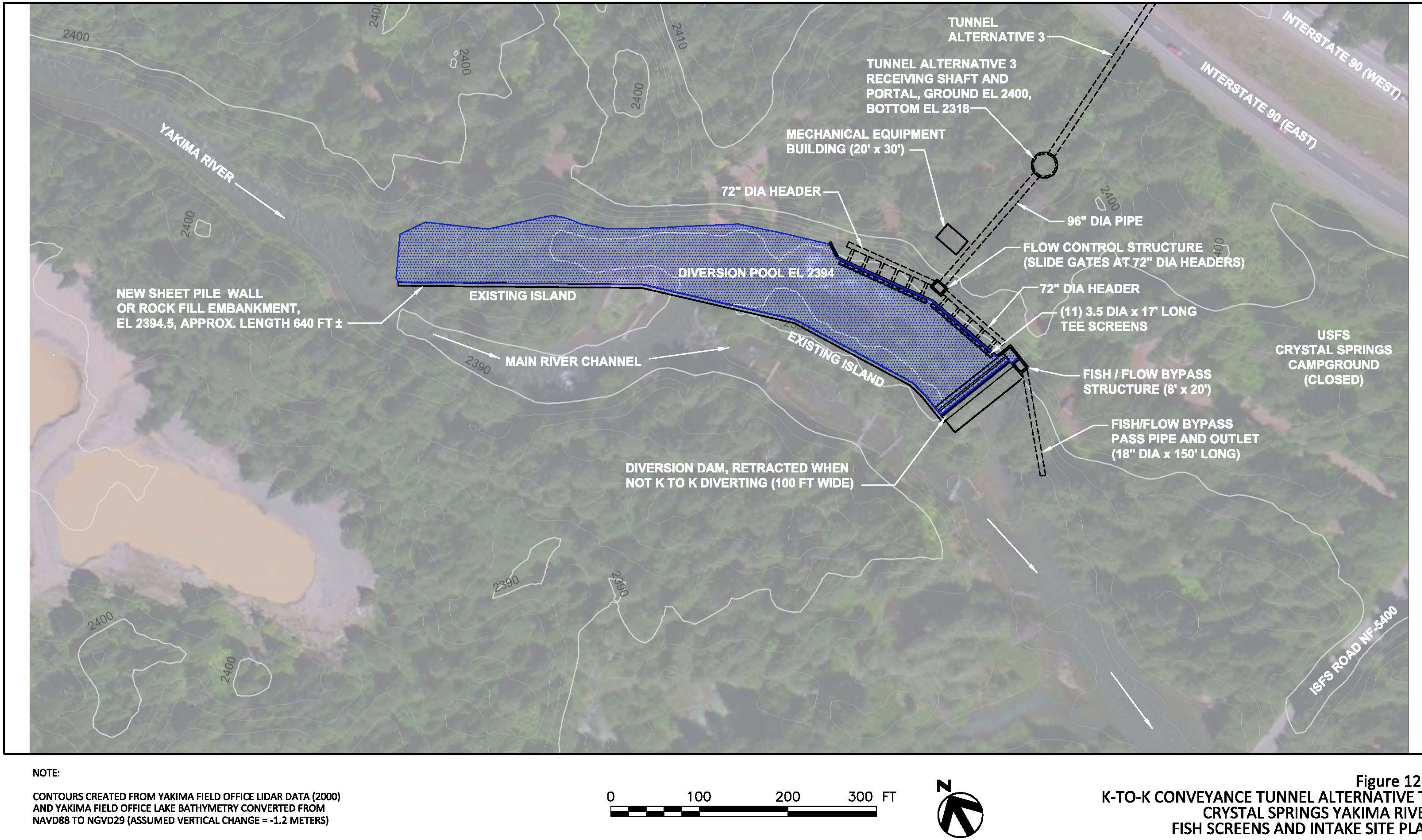
DESIGNED JP
DRAWN AB
CHECKED JN
TECH. APPR. NAME - TITLE
APPROVED ADMINISTRATIVE APPROVAL - NAME - TITLE
BOISE, ID 04.29.2013

FIGURE 12-3

PRELIMINARY CONCEPT DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

SHEET OF

September 12, 2013
AutoCAD Rel. 17.1s



NOTE:

CONTOURS CREATED FROM YAKIMA FIELD OFFICE LIDAR DATA (2000) AND YAKIMA FIELD OFFICE LAKE BATHYMETRY CONVERTED FROM NAVD88 TO NGVD29 (ASSUMED VERTICAL CHANGE = -1.2 METERS)

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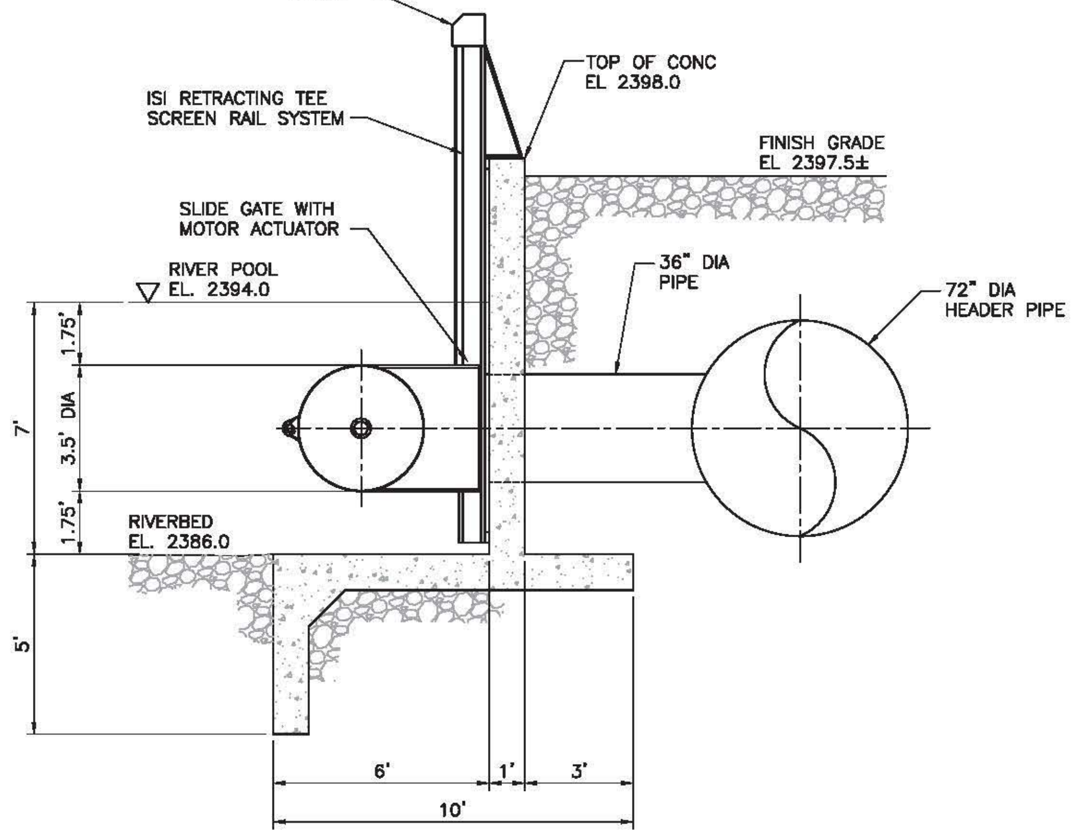
Figure 12-4
K-TO-K CONVEYANCE TUNNEL ALTERNATIVE T3
CRYSTAL SPRINGS YAKIMA RIVER
FISH SCREENS AND INTAKE SITE PLAN

PRELIMINARY CONCEPT DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE



SCREENED INTAKE SECTION

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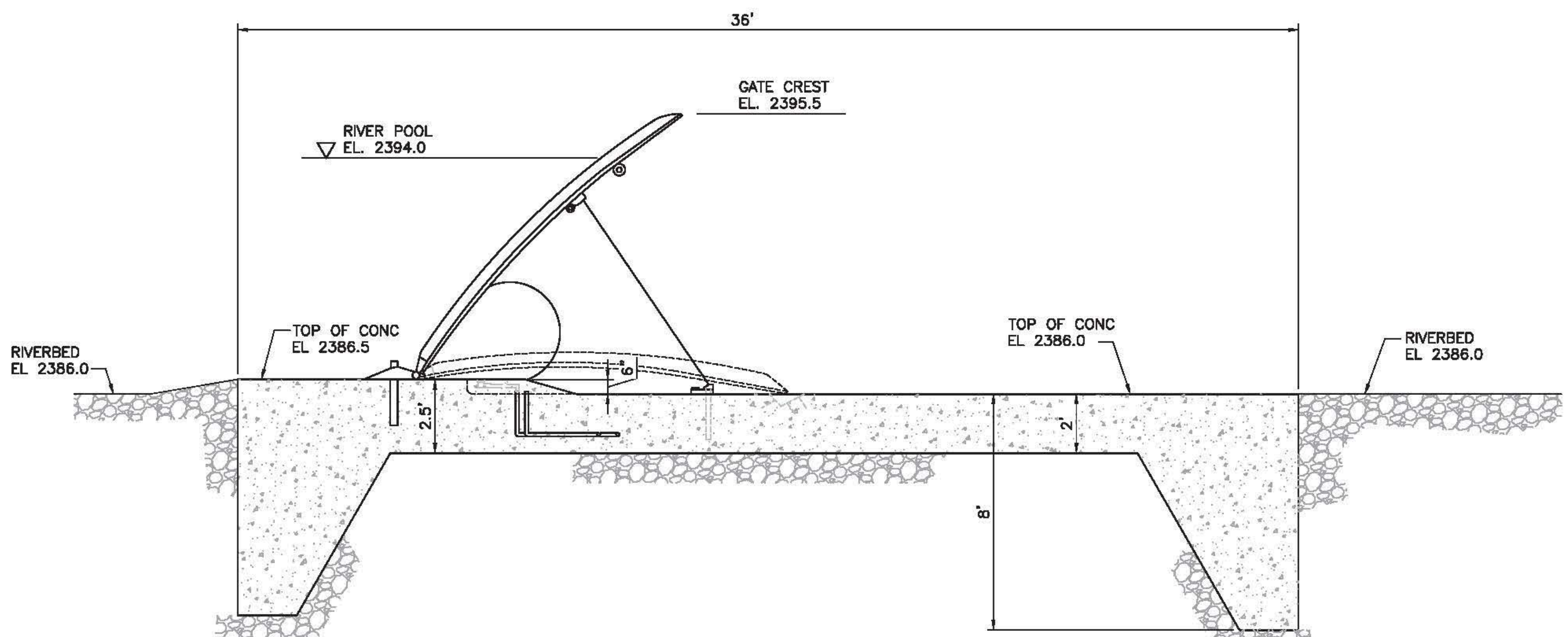

DIVERSION DAM SECTION

0 2 4 8 FT

PRELIMINARY CONCEPT DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN IWRS PLAN

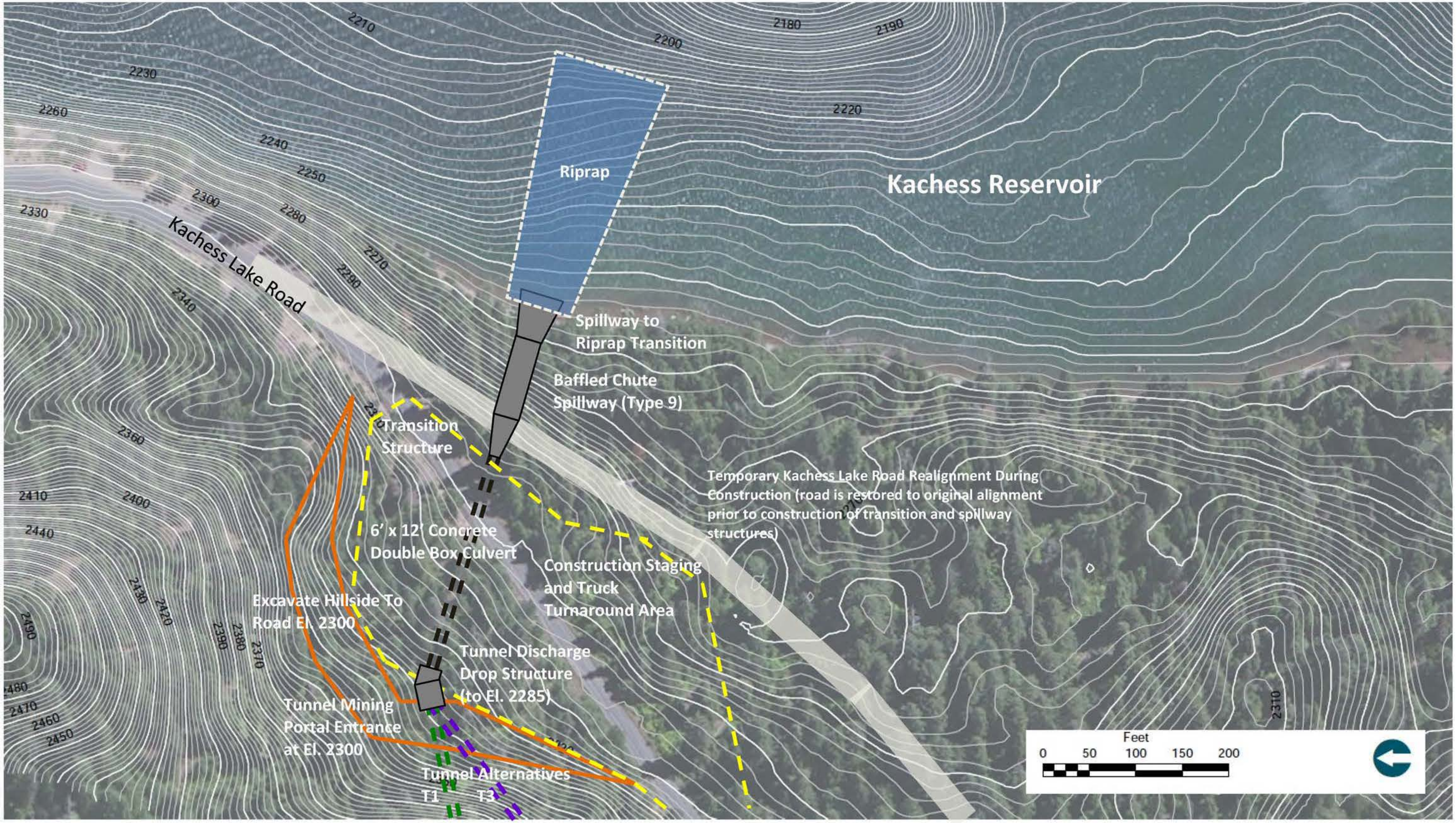
K-TO-K CONVEYANCE TUNNEL ALTERNATIVE 3
CRYSTAL SPRINGS YAKIMA RIVER
INTAKE AND DIVERSION DAM SECTIONS

DESIGNED JP
DRAWN AB
CHECKED JN
TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE
BOISE, ID 04.29.2013

FIGURE 12–5

SHEET OF

September 12, 2013
AutoCAD Rel. 17.1s



Contours created from Yakima Field Office LiDAR data (2000) and Yakima Field Office lake bathymetry data converted from NAVD88 to NGVD29 (assumed vertical change = -1.2 meters).

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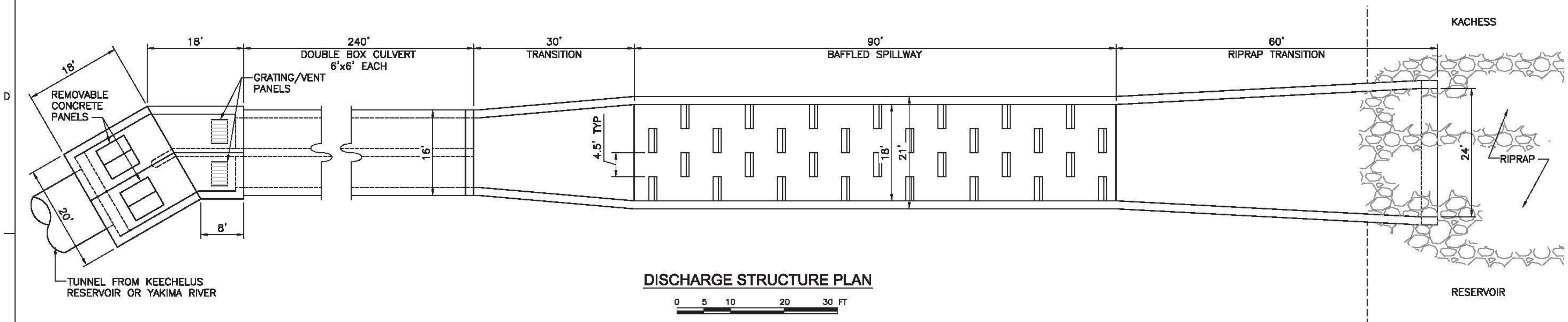
Figure 12-6

K-to-K Tunnel Alternatives T1 and T3 Lake Kachess Tunnel Mining Portal and Discharge Spillway Site Plan



DISCHARGE STRUCTURE PLAN

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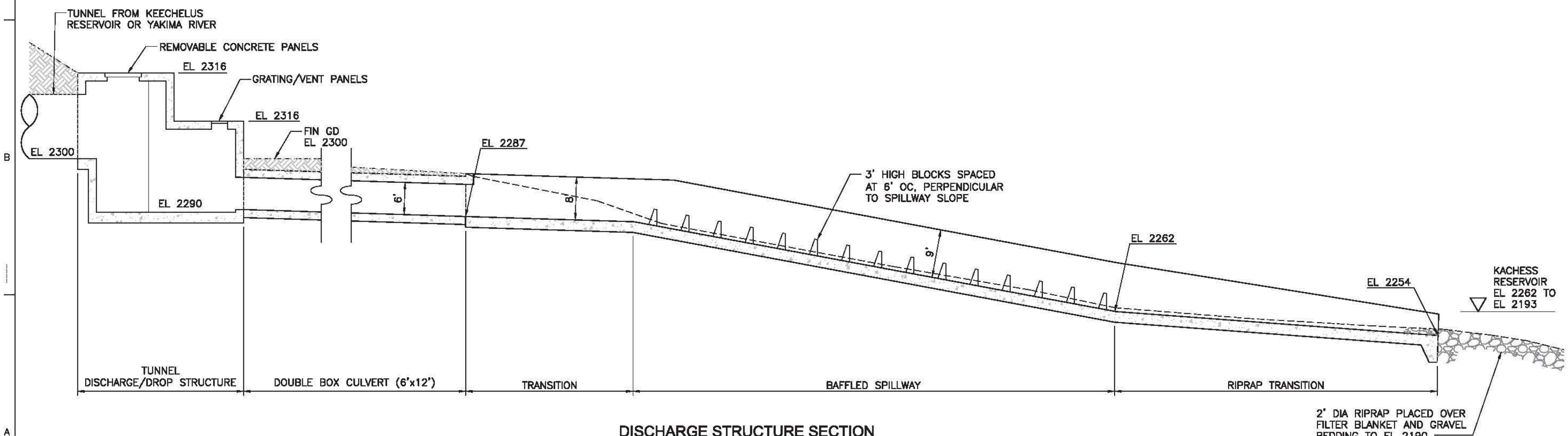

DISCHARGE STRUCTURE SECTION

0 5 10 20 30 FT

PRELIMINARY CONCEPT DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN IWRS PLAN

K-TO-K CONVEYANCE KACHESS RESERVOIR
TUNNEL DISCHARGE STRUCTURE
PLAN AND SECTION

DESIGNED JP
DRAWN AB
CHECKED JN
TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE
BOISE, ID 04.29.2013

FIGURE 12-7

SHEET OF

September 12, 2013

AutoCAD Rel. 17.1s

Appendix B

Cost Estimates

Keechelus to Kachess Tunnel Alt 1 – Estimate WorkArea Report

Keechelus to Kachess Tunnel Alt 3 – Estimate WorkArea Report

Estimate WorkArea Report

Engineer	HDR Engineering, Inc
Labor rate table	CONC2013
Equipment rate table	CONC2013
Project Name 1	Keechelus to Kachees
Project Name 2	Tunnel Alt 1
Project Info 1	Yakima River Basin
Project Info 2	Water Storage Study
Project Location 1	YRSSW
Project Location 2	PN
Design Stage 1	Appriaisal
Estimate Version	20130528v1
Upper Range +%	40
Lower Range -%	20
Labor Rate Table	1stQtr 2013 Union
Equip Rate Table	1st Qtr 2013
Competition	*Open*
Cost index	989-WA-YAKIMA

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
001.00	***INTAKE SCREEN & STRUCTURE***								
DIVISION 02	**SITE CONSTRUCTION**								
02316.000	Excavation, Dewatering, Cofferedam, Backfill	1.00	ls			707,000			707,000
Per John Nelson									
DIVISION 02 SITE CONSTRUCTION						**707,000**			**707,000**
1.00	**ls**								
0.13	Labor hours								
0.05	Equipment hours								
DIVISION 03	**CONCRETE**								
03002.200	Concrete for Steel Piles	85.00	cy			42,500			42,500
Per John Nelson									
DIVISION 03 CONCRETE						**42,500**			**42,500**
47.00	**cy**								
DIVISION 05	**METALS**								
05120.000	Structural & Miscellaneous Metals	1.00	ls			771,000			771,000
Per John Nelson									
DIVISION 05 METALS						**771,000**			**771,000**
1.00	**ls**								
DIVISION 07	**THERMAL& MOISTURE PROTECTION**								
07415.000	Aluminum Standing Seam Metal	800.00	sf			35,200			35,200
Per John Nelson									
DIVISION 07 THERMAL& MOISTURE PROTECTION						**35,200**			**35,200**
800.00	**sf**								
DIVISION 08	**DOORS & WINDOWS**								
08100.000	Doors	1.00	ls			12,100			12,100
Per John Nelson									

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 08 DOORS & WINDOWS						**12,100**			**12,100**
1.00 ls									
DIVISION 09	**FINISHES**								
09904.000	Painting and Protective Coatings	1.00	ls			50,000			50,000
Per John Nelson									
DIVISION 09 FINISHES						**50,000**			**50,000**
1.00 ls									
0.02 Labor hours									
DIVISION 13	**SPECIAL CONSTRUCTION**								
13300.000	Fish Screens - SS Wedge Wire Cylinders, I&C	2,500.00	sf			1,200,000			1,200,000
4' 9" x 34' lg									
DIVISION 13 SPECIAL CONSTRUCTION						**1,200,000**			**1,200,000**
1.00 ls									
350,000.00 Labor hours									
50,000.00 Equipment hours									
DIVISION 15	**MECHANICAL**								
15050.000	Basic Mechanical Materials & Methods	1.00	ls			140,000			140,000
Per John Nelson									
DIVISION 15 MECHANICAL						**140,000**			**140,000**
1.00 ls									
25.00 Labor hours									
DIVISION 16	**ELECTRICAL**								
16010.000	Electrical: Basic Requirements	1.00	ls			210,000			210,000
Per John Nelson									
DIVISION 16 ELECTRICAL						**210,000**			**210,000**
1.00 ls									

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
001.00 INTAKE SCREEN & STRUCTURE				***0***	***0***	***3,167,800***	***0***	***0***	***3,167,800***
1.00 LS									
350,025.141 Labor hours									
50,000.05 Equipment hours									
002.00	***96" PIPELINE & FLOW CONTROL STRUCTURE***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.205	Task Specific Equipment - Personnel and Light Material Hosit	30.00	dys				30,071		30,071
01500.210	Task Specific Equipment - Crane	30.00	dys				52,779		52,779
DIVISION 01 GENERAL REQUIREMENTS							**82,850**		**82,850**
1.00 ls									
480.00 Equipment hours									
DIVISION 02	**SITE CONSTRUCTION**								
02316.100	Shaft Construction	1.00	ls	34,521	18,288		52,341	413,517	518,668
DIVISION 02 SITE CONSTRUCTION				**34,521**	**18,288**		**52,341**	**413,517**	**518,668**
1.00 ls									
603.97 Labor hours									
642.54 Equipment hours									
DIVISION 03	**CONCRETE**								
03002.100	Concrete_Foundations	184.00	cy	38,759	63,573		2,652		104,984
03002.300	Concrete_Slip Forming Shafts	342.00	cy	58,163	120,364		5,170		183,698
03002.600	Concrete_Elevated Slab	49.00	cy	41,711	13,500		3,223		58,435
DIVISION 03 CONCRETE				**138,634**	**197,438**		**11,045**		**347,117**
266.00 cy									
2,549.50 Labor hours									
422.99 Equipment hours									
DIVISION 08	**DOORS & WINDOWS**								

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
08305.000	Access Doors	2.00	ea	433	5,042				5,475
Control valve vault access									
DIVISION 08 DOORS & WINDOWS				**433**	**5,042**				**5,475**
2.00	**ls**								
7.111	Labor hours								
DIVISION 13	**SPECIAL CONSTRUCTION**								
13121.000	Metal Building Systems	256.00	sf	3,904	4,082		1,718		9,703
Control building for valves at Outlet valves bifucation per figure 8									
DIVISION 13 SPECIAL CONSTRUCTION				**3,904**	**4,082**		**1,718**		**9,703**
1.00	**ls**								
59.732	Labor hours								
8.532	Equipment hours								
DIVISION 15	**MECHANICAL**								
15061.100	Pipe: Steel- 26" and larger	680.00	lf	121,305	898,391		230,952		1,250,648
96" Steel pipe and fittings, epoxy coated, field cement lined, budget pricing from NWPipe. For cement lining fitting length assumed to be 2 pipe dia. for 90/45, 3 for tees and wyes.									
15115.000	Water Control Gates	2.00	ea	23,828	100,000		6,266		130,095
DIVISION 15 MECHANICAL				**145,134**	**998,391**		**237,219**		**1,380,743**
1.00	**ls**								
2,245.944	Labor hours								
2,004.092	Equipment hours								
002.00 96" PIPELINE & FLOW CONTROL STRUCTURE				***322,625***	***1,223,241***	***0***	***385,172***	***413,517***	***2,344,554***
1.00	***LS***								
5,466.255	Labor hours								
3,558.152	Equipment hours								
003.00	***96" DIA. LINED TUNNEL***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.500	Mobilization /Demobilization - Subcontractors	1.00	ls			75,000		0	75,000
Mobilization of cement lining specialty contractor included.									

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 01 GENERAL REQUIREMENTS						**75,000**		**0**	**75,000**
1.00 ls									
DIVISION 02	**SITE CONSTRUCTION**								
02400.100	Tunneling	1,150.00	lf					2,688,914	2,688,914
DIVISION 02 SITE CONSTRUCTION								**2,688,914**	**2,688,914**
1.00 ls									
DIVISION 15	**MECHANICAL**								
02400.100	Tunneling			28,808			48,535		77,342
DIVISION 15 MECHANICAL				**28,808**			**48,535**		**77,342**
1.00 ls									
531.031 Labor hours									
531.031 Equipment hours									
003.00 96" DIA. LINED TUNNEL				***28,808***	***0***	***75,000***	***48,535***	***2,688,914***	***2,841,256***
1,150.00 LF									
531.031 Labor hours									
531.031 Equipment hours									

004.00 12' DIA MAIN TUNNEL, 1/2 LINED

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.100	Non-Task Specific Equipment - Generator for all operations	240.00	dys				333,603		333,603
01500.500	Mobilization /Demobilization - Subcontractors	1.00	ls			325,000		0	325,000
Mobilization of cement lining specialty contractor included.									
DIVISION 01 GENERAL REQUIREMENTS						**325,000**	**333,603**	**0**	**658,603**
1.00 ls									
3,840.00 Equipment hours									
DIVISION 02	**SITE CONSTRUCTION**								

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
02400.100	Tunneling	19,700.00	lf	8,819,678	3,711,965		2,915,673	47,999,904	63,447,220
DIVISION 02 SITE CONSTRUCTION				**8,819,678**	**3,711,965**		**2,915,673**	**47,999,904**	**63,447,220**
1.00	**ls**								
194,207.242	Labor hours								
39,757.371	Equipment hours								
004.00 12' DIA MAIN TUNNEL, 1/2 LINED				***8,819,678***	***3,711,965***	***325,000***	***3,249,276***	***47,999,904***	***64,105,823***
19,700.00	***LF***								
194,207.242	Labor hours								
43,597.371	Equipment hours								

005.00 DEEP TUNNEL SHAFT

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.200	Task Specific Equipment	80.00		12,409			15,871		28,280
Additional equipment required for installation of the in water piping									
01500.205	Task Specific Equipment - Personnel and Light Material Hosit	80.00	dys				87,160		87,160
01500.210	Task Specific Equipment - Crane	80.00	dys				140,744		140,744
DIVISION 01 GENERAL REQUIREMENTS				**12,409**			**243,775**		**256,184**
1.00	**ls**								
213.333	Labor hours								
49,600.00	Equipment hours								
DIVISION 02	**SITE CONSTRUCTION**								
02316.100	Shaft Construction	1.00	ls	91,883	33,867		144,026	774,176	1,043,951
02930.000	Seeding, Sodding, and Landscaping	1.00	ls			15,150			15,150
DIVISION 02 SITE CONSTRUCTION				**91,883**	**33,867**	**15,150**	**144,026**	**774,176**	**1,059,101**
1.00	**ls**								
1,633.763	Labor hours								
1,705.192	Equipment hours								
DIVISION 03	**CONCRETE**								

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
03002.100	Concrete_Foundations	184.00	cy	38,759	63,573		2,652		104,984
03002.300	Concrete_Slip Forming Shafts	1,335.00	cy	227,042	469,842		20,182		717,066
03002.600	Concrete_Elevated Slab	147.00	cy	64,254	40,501		4,835		109,591
DIVISION 03 CONCRETE				**330,055**	**573,917**		**27,668**		**931,641**
1,519.00	**cy**								
6,026.22	Labor hours								
1,323.06	Equipment hours								
DIVISION 15	**MECHANICAL**								
15890.000	HVAC: Ductwork	1.00	ls					27,422	27,422
DIVISION 15 MECHANICAL								**27,422**	**27,422**
1.00	**ls**								
005.00 DEEP TUNNEL SHAFT				***434,347***	***607,784***	***15,150***	***415,469***	***801,597***	***2,274,348***
1.00	***LS***								
7,873.315	Labor hours								
52,628.25	Equipment hours								
010.00	***DISCHARGE STRUCTURE AND SPILLWAY***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.000	Temporary Facilities & Controls	1.00	ls	147,968	23,470			105,040	276,478
DIVISION 01 GENERAL REQUIREMENTS				**147,968**	**23,470**			**105,040**	**276,478**
1.00	**ls**								
2,666.650	Labor hours								
DIVISION 02	**SITE CONSTRUCTION**								
02072.000	Demolition, Cutting and Patching	12,444.00	sy	54,227			31,054		85,281
02110.000	Site Clearing	15.00	ac	42,600			76,691		119,291
Assumes no Burning, Clearing from 50+00 to 115+00 100' wide, Clearing from 115+00 to 270+00 150' wide									
02200.000	Earthwork	23,611.00	cy	261,592	141,191		421,591		824,374
02271.000	Stone Revetment (Rip Rap)	1.00	ls	14,799	219,341		16,670		250,810

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
02513.000	Asphaltic Concrete Vehicular Paving	15,575.00	sy	36,452	310,718		37,288		384,458
DIVISION 02 SITE CONSTRUCTION				**409,670**	**671,250**		**583,294**		**1,664,214**
1.00	**ls**								
7,301.57	Labor hours								
6,476.39	Equipment hours								
DIVISION 03	**CONCRETE**								
03002.100	Concrete_Foundations	550.00	cy	87,742	153,003		9,014		249,759
03002.360	Concrete_Walls_Exterior	562.00	cy	221,215	160,502		4,895		386,612
03002.600	Concrete_Elevated Slab	247.00	cy	59,562	72,552		1,724		133,839
DIVISION 03 CONCRETE				**368,518**	**386,058**		**15,634**		**770,209**
1,379.00	**cy**								
6,775.722	Labor hours								
391.57	Equipment hours								
010.00 DISCHARGE STRUCTURE AND SPILLWAY				***926,156***	***1,080,777***	***0***	***598,928***	***105,040***	***2,710,901***
1.00	***LS***								
16,743.94	Labor hours								
6,867.954	Equipment hours								

Estimate Totals

Description	Amount	Totals	Rate
Labor	10,531,613		
Material	6,623,767		
Subcontract	3,582,950		
Equipment	4,697,380		
Other	52,008,972		
Subtotal		**77,444,682**	
Contractor's Fld Ovhd	1,548,894		2.000 %
Mobilization	3,872,234		5.000 %
Subtotal w/ mobilization		**82,865,810**	
Unlisted Items Minor	2,999,818		4.000 %
Design and Scope Changes Minor	2,999,818		4.000 %
Cost Est Refinements Minor	1,499,909		2.000 %
Contractor's Fee	5,421,921		6.000 %
Contractor's Bonds & Insurance	1,355,480		1.500 %
Procurement Strategy-Open Comp			
Contract Cost		**97,142,756**	
Contingencies	24,285,689		25.000 %
Field Cost		**121,428,445**	
Sales Tax Estimate (Mat & Eq)	921,637		8.200 %
Escal to NTP (NOTINCL)			

AACE Classification Accuracy Range

Upper Range +40%

Lower Range -20%

Estimate Totals

Forecasted Feature Bid **122,350,082**

.

AACE Classification Accuracy Range

Upper Range +40% **Lower Range -20%**

Engineer	HDR Engineering, Inc
Labor rate table	CONC2013
Equipment rate table	CONC2013
Project Name 1	Keechelus to Kachees
Project Name 2	Tunnel Alt 3
Project Info 1	Yakima River Basin
Project Info 2	Water Storage Study
Project Location 1	YRSSW
Project Location 2	PN
Design Stage 1	Appriaisal
Estimate Version	20130528V1
Upper Range +%	40
Lower Range -%	20
Labor Rate Table	1stQtr 2013 Union
Equip Rate Table	1st Qtr 2013
Competition	*Open*
Cost index	989-WA-YAKIMA

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
001.00	***INTAKE SCREEN & CONNECTERS TO MAIN TUNNEL***								
DIVISION 02	**SITE CONSTRUCTION**								
02316.000	Excavation, Dewatering, Cofferedam, Backfill	200.00	ls			352,000			352,000
DIVISION 02 SITE CONSTRUCTION						**352,000**			**352,000**
1.00	**ls**								
0.13	Labor hours								
0.05	Equipment hours								
DIVISION 03	**CONCRETE**								
03002.200	Concrete_	462.00	cy			277,000			277,000
DIVISION 03 CONCRETE						**277,000**			**277,000**
462.00	**cy**								
DIVISION 05	**METALS**								
05120.000	Structural Steel	1.00	ls			205,000			205,000
DIVISION 05 METALS						**205,000**			**205,000**
1.00	**ls**								
DIVISION 07	**THERMAL& MOISTURE PROTECTION**								
07415.000	Aluminum Standing Seam Metal	750.00	sf			33,000			33,000
DIVISION 07 THERMAL& MOISTURE PROTECTION						**33,000**			**33,000**
1.00	**ls**								
20.003	Labor hours								
DIVISION 08	**DOORS & WINDOWS**								
08100.000	Doors	1.00	ls			9,350			9,350
Per John Nelson									
DIVISION 08 DOORS & WINDOWS						**9,350**			**9,350**
1.00	**ls**								
8.00	Labor hours								

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 09	**FINISHES**								
09904.000	Painting and Protective Coatings	1.00	ls			20,000			20,000
DIVISION 09 FINISHES						**20,000**			**20,000**
1.00 ls									
0.02 Labor hours									
DIVISION 13	**SPECIAL CONSTRUCTION**								
13300.000	Fish Screens - SS Wedge Wire Cylinders, Dam, I&C	1,250.00	sf			1,100,000			1,100,000
3' 6"" dia x 17' lg, ss, Budget pricing from ISI									
DIVISION 13 SPECIAL CONSTRUCTION						**1,100,000**			**1,100,000**
1.00 ls									
175,032.00 Labor hours									
25,000.00 Equipment hours									
DIVISION 15	**MECHANICAL**								
15050.000	Basic Mechanical Materials & Methods	1.00	ls			127,000			127,000
DIVISION 15 MECHANICAL						**127,000**			**127,000**
1.00 ls									
DIVISION 16	**ELECTRICAL**								
16010.000	Electrical: Basic Requirements	1.00	ls			385,000			385,000
200 kw generator									
DIVISION 16 ELECTRICAL						**385,000**			**385,000**
1.00 LS									
001.00 INTAKE SCREEN & CONNECTERS TO MAIN TUNNEL				***0***	***0***	***2,508,350***	***0***	***0***	***2,508,350***
1.00 LS									
175,060.144 Labor hours									
25,000.05 Equipment hours									

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
002.00	***96" PIPELINE TO DEEP SHAFT***								
DIVISION 15	**MECHANICAL**								
15061.100	Pipe: Steel- 26" and larger	150.00	lf	17,880	509,812		22,832		550,524
96" Steel pipe and fittings, epoxy coated, field cement lined, budget pricing from NWPipe. For cement lining fitting length assumed to be 2 pipe dia. for 90/45, 3 for tees and wyes.									
15115.000	Water Control Gates	2.00	ea	23,828	100,000		6,266		130,095
DIVISION 15 MECHANICAL				**41,709**	**609,812**		**29,098**		**680,619**
1.00 ls									
614.392 Labor hours									
365.360 Equipment hours									
002.00 96" PIPELINE TO DEEP SHAFT				***41,709***	***609,812***	***0***	***29,098***	***0***	***680,619***
1.00 LS									
614.392 Labor hours									
365.360 Equipment hours									
003.00	***MAIN TUNNEL 12' DIAMETER, 1/2 LINED***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.100	Non-Task Specific Equipment - Generator for all operations	240.00	dys				333,603		333,603
01500.500	Mobilization /Demobilization - Subcontractors	1.00	ls			325,000		0	325,000
Mobilization of cement lining specialty contractor included.									
DIVISION 01 GENERAL REQUIREMENTS						**325,000**	**333,603**	**0**	**658,603**
1.00 ls									
3,840.00 Equipment hours									
DIVISION 02	**SITE CONSTRUCTION**								
02400.100	Tunneling	17,700.00	lf	7,925,740	3,335,116		2,622,127	43,131,089	57,014,072

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
DIVISION 02 SITE CONSTRUCTION				**7,925,740**	**3,335,116**		**2,622,127**	**43,131,089**	**57,014,072**
1.00 ls									
174,517.700 Labor hours									
35,748.02 Equipment hours									
003.00 MAIN TUNNEL 12' DIAMETER, 1/2 LINED				***7,925,740***	***3,335,116***	***325,000***	***2,955,730***	***43,131,089***	***57,672,675***
17,700.00 LF									
174,517.700 Labor hours									
39,588.02 Equipment hours									
005.00	***DEEP TUNNEL SHAFT***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.200	Task Specific Equipment	1.00	ls	12,409			15,871		28,280
Additional equipment required for installation of the in water piping									
01500.205	Task Specific Equipment - Personnel and Light Material Hosit	70.00	dys				70,165		70,165
01500.210	Task Specific Equipment - Crane	70.00	dys				123,151		123,151
DIVISION 01 GENERAL REQUIREMENTS				**12,409**			**209,187**		**221,596**
1.00 ls									
213.333 Labor hours									
1,440.00 Equipment hours									
DIVISION 02	**SITE CONSTRUCTION**								
02316.100	Shaft Construction	1.00	ls	57,174	20,772		89,708	472,308	639,963
02930.000	Seeding, Sodding, and Landscaping	1.00	ls			15,150			15,150
DIVISION 02 SITE CONSTRUCTION				**57,174**	**20,772**	**15,150**	**89,708**	**472,308**	**655,113**
1.00 ls									
1,017.62 Labor hours									
1,059.141 Equipment hours									
DIVISION 03	**CONCRETE**								

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
03002.100	Concrete_Foundations	184.00	cy	38,759	63,573		2,652		104,984
03002.300	Concrete_Walls Exterior_Pipe connection to existing tower	815.00	cy	138,721	287,142		12,316		438,179
03002.600	Concrete_Elevated Slab	147.00	cy	64,254	40,501		4,835		109,591
DIVISION 03 CONCRETE				**241,735**	**391,217**		**19,803**		**652,754**
1,519.00	**cy**								
4,441.293	Labor hours								
868.40	Equipment hours								
DIVISION 15	**MECHANICAL**								
15890.000	HVAC: Ductwork	1.00	ls					25,022	25,022
DIVISION 15 MECHANICAL								**25,022**	**25,022**
1.00	**ls**								
005.00 DEEP TUNNEL SHAFT				***311,318***	***411,989***	***15,150***	***318,697***	***497,330***	***1,554,484***
1.00	***LS***								
5,672.243	Labor hours								
3,367.54	Equipment hours								
010.00	***DISCHARGE STRUCTURE AND SPILLWAY***								
DIVISION 01	**GENERAL REQUIREMENTS**								
01500.000	Temporary Facilities & Controls	1.00	ls	147,968	23,470			105,040	276,478
Field Cement lining pricing from Spinello									
DIVISION 01 GENERAL REQUIREMENTS				**147,968**	**23,470**			**105,040**	**276,478**
1.00	**ls**								
2,666.650	Labor hours								
DIVISION 02	**SITE CONSTRUCTION**								
02072.000	Demolition, Cutting and Patching	9,600.00	sy	54,227			31,054		85,281
Demolition of exisitng bypass piping 22" and exisitng aquaduct 150'									
02110.000	Site Clearing	15.00	ac	42,600			76,691		119,291
Assumes no Burning, Clearing from 50+00 to 115+00 100' wide, Clearing from 115+00 to 270+00 150' wide									

Description		Quantity		Labor Amount	Material Amount	Subcontract Amount	Equipment Amount	Other Amount	Total Amount
02200.000	Earthwork	3,570.00	cy	261,592	141,191		421,591		824,374
Excavation and backfill of control valve vault									
02271.000	Stone Revetment (Rip Rap)	1.00	ls	14,799	219,341		16,670		250,810
02513.000	Asphaltic Concrete Vehicular Paving	15,575.00	sy	36,452	310,718		37,288		384,458
Scope of work includes 12,900 lf of 24' wide temporary vehicular traffic roadway, built to DOT standards and the replacement of the same amount of permanent road once the overburden is put back in place.									
DIVISION 02 SITE CONSTRUCTION				**409,670**	**671,250**		**583,294**		**1,664,214**
1.00 ls									
7,301.57 Labor hours									
6,476.39 Equipment hours									
DIVISION 03	**CONCRETE**								
03002.100	Concrete_Foundations	550.00	cy	87,742	153,003		9,014		249,759
03002.360	Concrete_Walls_Exterior	562.00	cy	221,215	160,502		4,895		386,612
03002.600	Concrete_Elevated Slab	247.00	cy	59,562	72,552		1,724		133,839
DIVISION 03 CONCRETE				**368,518**	**386,058**		**15,634**		**770,209**
1,359.00 cy									
6,775.722 Labor hours									
391.57 Equipment hours									
010.00 DISCHARGE STRUCTURE AND SPILLWAY				***926,156***	***1,080,777***	***0***	***598,928***	***105,040***	***2,710,901***
1.00 LS									
16,743.94 Labor hours									
6,867.954 Equipment hours									

Estimate Totals

Description	Amount	Totals	Rate
Labor	9,204,923		
Material	5,437,695		
Subcontract	2,848,500		
Equipment	3,902,452		
Other	43,733,459		
Subtotal		**65,127,029**	
Contractor's Fld Ovhd	1,302,541		2.000 %
Mobilization	3,256,351		5.000 %
Subtotal w/ mobilization		**69,685,921**	
Unlisted Items Minor	2,520,454		4.000 %
Design and Scope Changes Minor	2,520,454		4.000 %
Cost Est Refinements Minor	1,260,227		2.000 %
Contractor's Fee	4,559,223		6.000 %
Contractor's Bonds & Insurance	1,139,806		1.500 %
Procurement Strategy-Open Comp			
Contract Cost		**81,686,085**	
Contingencies	20,421,522		25.000 %
Field Cost		**102,107,607**	
Sales Tax Estimate (Mat & Eq)	762,092		8.200 %
Escal to NTP (NOTINCL)			

AACE Classification Accuracy Range

Upper Range +40% **Lower Range -20%**

Estimate Totals

Forecasted Feature Bid **102,869,699**

AACE Classification Accuracy Range

Upper Range +40% **Lower Range -20%**