Yakima River Basin Integrated Water Resource Management Plan

Feasibility Design Report – Draft

Keechelus-to-Kachess Conveyance

U.S. Bureau of Reclamation
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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

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Feasibility Design Report

Yakima Basin Integrated Water Resources Management Plan
Keechelus-to-Kachess Conveyance, Washington
Pacific Northwest Region

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Prepared by: HDR Engineering, Inc.

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Date	Description	Team Leader	Peer Review

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Contents

List of Tables

List of Figures

Appendices

Glossary and List of Acronyms

cfs	cubic feet per second
cy	cubic yards
Corps	U.S. Army Corps of Engineers
DAHP	Department of Archaeology and Historic Preservation
D/d	depth over tunnel diameter
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
El.	elevation
fps	feet per second
frazil	Needle-shaped ice crystals in water, resembling slush
Froude number	The ratio of a characteristic velocity to a gravitational wave velocity
gpd	gallons per day
gpm	gallons per minute
HP	horsepower
Hv	velocity head
I-90	Interstate-90
Integrated Plan	Yakima Basin Integrated Water Resource Management Plan
KDRPP	Kachess Drought Relief Pumping Plant
KKC	Keechelus-to-Kachess Conveyance
mm	millimeters
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
OWNF	Okanogan-Wenatchee National Forest
PHA	peak horizontal ground acceleration
PLC	programmable logic control
psf	pounds per square foot
SEPA	State Environmental Policy Act
Service	United States Fish and Wildlife Service
TBM	tunnel boring machine
TSC	Reclamation Technical Service Center
USFS	United States Forest Service
WDFW	Washington State Department of Fish and Wildlife
WSDOT	Washington State Department of Transportation

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1.0 Executive Summary

This Feasibility Design Report describes project alternatives and technical considerations to convey water from the U.S. Department of the Interior Bureau of Reclamation's Keechelus Reservoir to Kachess Reservoir as part of the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan) (Reclamation and Ecology, 2011b). The purpose of the Keechelus-to-Kachess Conveyance (KKC) 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 to provide benefits to fish and wildlife, particularly Chinook and steelhead. In the event that the separate Kachess Drought Relief Pumping Plant (KDRPP) is constructed, an additional purpose of the KKC project is to accelerate refill of Kachess Reservoir in years following pumping by KDRPP.

The KKC project is currently at a feasibility stage of development. Previous technical memoranda described initial project criteria and a pipeline alternative (Reclamation and Ecology, 2011a); screening of alternatives (Reclamation and Ecology, 2013); value analysis of alternatives (Reclamation, 2014); interpretation of geotechnical conditions (Reclamation and Ecology, 2014d); hydraulics review (Reclamation and Ecology, 2014e); the project design criteria (Reclamation and Ecology, 2014b); and field cost estimates (Reclamation and Ecology, 2014c). The project team also performed hydrologic analysis of the Yakima River system to evaluate project performance and establish the appropriate capacity for the KKC project (Reclamation and Ecology, 2014a).

This report considers two alternative tunnel alignments from the Keechelus Reservoir to the Kachess Reservoir: the North Tunnel Alignment and the South Tunnel Alignment.

1.1 Background

The Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan) offers an approach to improving water management in the Yakima River basin of central Washington State. It was developed by Reclamation and the Washington State Department of Ecology in conjunction with the Yakama Nation and Yakima River basin stakeholders. The goals of the Integrated Plan are to protect, mitigate, and enhance fish and wildlife habitat; provide increased operational flexibility to manage instream flows to meet ecological objectives, and improve the reliability of the water supply for irrigation, municipal supply and domestic uses. A Final Programmatic Environmental Impact Statement (PEIS) analyzing broad effects of the Integrated Plan on environmental resources was issued in 2012 (Reclamation and Ecology, 2012d). Programmatic Planning and Economics reports: the Framework for Implementation (cite), Four Account Analysis and a Preliminary Cost Allocation were also prepared. The Record of Decision for the Programmatic EIS selected the Integrated Plan as the preferred alternative. The KKC is a component of the Integrated Plan structural and operational changes element.

The Integrated Plan is to be implemented with a balanced approach. A balanced approach means advancing projects associated with each element of the plan (appraisal analysis, feasibility study to implementation) during the same development phase. Components of the Integrated Plan are concurrently being advanced in the Initial Development Phase

(2013-2023). KKC is included in the Initial Development Phase, covering the first ten-year period (2013-2023), which advances all seven plan elements and represents approximately 1/3 of the estimated plan cost (about $900 million). Other key projects include implementation of Cle Elum Fish Passage, Cle Elum Pool Raise, and Kachess Drought Relief Pumping Plant; and various projects associated with each element of the Integrated Plan such as habitat and tributary restoration, agricultural conservation, and groundwater recharge projects.

As a whole, Integrated Plan activities benefit fish and irrigation and offer a synergy that would otherwise be unattainable without the plan.

1.2 North Tunnel Alignment

The North Tunnel Alignment Alternative would divert water from the Keechelus Reservoir outlet to the Yakima River. This alternative would include the following project elements:

- Keechelus Dam outlet channel diversion and intake, including fish screens.
- Conveyance from the outlet channel intake to the nearby Keechelus portal.
- Keechelus portal drop shaft and plunge pool.
- Deep tunnel from the Keechelus portal to the Kachess Road portal. The tunnel would be 10-foot diameter, concrete lined, and mined up slope from an at-grade Kachess portal to the Keechelus portal drop shaft.
- Kachess Road portal and discharge structure into Kachess Reservoir.

Both straight and curved North Tunnel alignments were considered during the Value Planning Analysis (Reclamation, 2014). A shorter straight North Tunnel Alignment from the Keechelus Portal to the Kachess Lake Road Portal may also be viable. However, due to the greater depth from the surface and associated anticipated rock mass pressures, the straight tunnel alignment may result in more robust and costly tunnel support systems than those required for the curved tunnel alignment. Geotechnical investigations (drilling and sampling of rock at the tunnel grade) are more feasible with the shallower depth curved tunnel alignment. Therefore, as a result of the Value Planning Analysis, the curved North Tunnel Alignment was carried forward in this Feasibility Design Report.

In the North Tunnel Alignment, the deep tunnel is approximately 21,390 feet long (4.1 miles). See Appendix A for drawings of the North Tunnel Alignment.

1.3 South Tunnel Alignment

The South Tunnel Alignment consists of two tunnel segments excavated from a portal shaft located in a construction staging area next to I-90 at Exit 62. Workers would mine Tunnel Segment A up gradient toward the same Keechelus portal drop shaft as described for the North Tunnel Alignment. The Tunnel Segment B would be mined up gradient northeast to a discharge structure at the Kachess Reservoir shoreline.

The following project elements located in the Keechelus Dam area would be the same as proposed for the North Tunnel Alignment:

- Keechelus Dam outlet channel diversion and intake, including fish screens.
- Conveyance from the outlet channel intake to the Keechelus portal.
- Keechelus portal drop shaft and plunge pool.

Additional project elements required for the South Tunnel Alignment include the following:

- I-90 Exit 62 portal.
- Deep tunnel mined up gradient from the I-90 Exit 62 portal to the Keechelus portal (Segment A).
- Deep tunnel mined up gradient from the I-90 Exit 62 portal to the Kachess Reservoir discharge portal (Segment B).
- Kachess Reservoir portal and discharge structure. (The Kachess Reservoir portal is different from the Kachess Road portal that is part of the North Tunnel Alignment.)

In the South Tunnel Alignment, Segment A of the deep tunnel is approximately 9,320 feet long, and Segment B of the deep tunnel is approximately 16,770 feet long, for a combined length of approximately 26,090 feet (4.9 miles). Both segments would be 10-foot diameter and concrete lined. See Appendix B for drawings of the South Tunnel Alignment.

1.4 Conveyance from Intake to Keechelus Portal

Under each of the alternatives described above, a 96-inch-diameter pipeline or tunnel would convey water from the Keechelus Dam outlet channel intake to the nearby Keechelus portal. There are two different options for constructing and aligning this pipeline, Options A and B. Option A and B are the same for both the North Tunnel Alignment or South Tunnel Alignment alternatives.

Option A would construct a conventional open-cut-and-cover pipeline from the outlet channel intake structure to the Keechelus portal. The pipeline would be approximately 1,440 feet long.

Although water would ultimately flow downslope from the outlet channel to the Keechelus portal, Option B would construct a shallow tunnel from the Keechelus portal to the outlet channel intake structure. The tunnel would be approximately 1,200 feet long. Construction of the tunnel would utilize trenchless installation methods, such as bore and jack. Option B would utilize the Keechelus portal excavation as the launch point of the tunneling equipment for the pipeline. This would require a larger Keechelus portal shaft than Option A to accommodate the additional use of the shaft excavation.

1.5 Combinations of Alternatives

Reclamation has identified four overall combinations of alternatives, using the two different tunnel alignments (North and South) and the two different conveyance options near Keechelus Reservoir (Options A and B). The four combinations are as follows:

- North Tunnel Alignment – Option A.
- North Tunnel Alignment – Option B.
- South Tunnel Alignment – Option A.
- South Tunnel Alignment – Option B.

1.6 Geotechnical Limitations

Reclamation completed four borings along a separate proposed alignment in the fall of 2013. Subsequent to that testing, Reclamation decided to focus attention on the North Tunnel Alignment and South Tunnel Alignment. Geotechnical information is limited regarding rock quality for the North Tunnel Alignment, and no geotechnical information is available for the South Tunnel Alignment. However, based upon local geology the project team has assumed that the full length of tunnel will be in rock. This assumption needs to be verified with additional geotechnical exploration. Depending upon the depth to and competency of the rock, the South Tunnel Alignment profile could either be modified or soft ground tunneling could be consideration for parts of the alignment.

Reclamation is currently planning a second round of geotechnical exploration, testing, and reporting that will most likely begin in the spring of 2015. Geological borings, monitoring wells and testing program are necessary to support the tunnel design effort and the dewatering system in the Keechelus area. Reclamation will also use the geological borings to look for the presence of cobbles, boulders, and hard rock layers, and to determine other tunneling and structural design parameters. Reclamation will use the findings of those additional explorations, testing, and reporting to help select the final alternative and to refine the design of the selected alternative.

1.7 Field Cost Estimates

Table 1 summarizes the field cost estimates developed for the four KKC project combinations listed in Section 1.4. Estimated costs are in 2014 dollars (second quarter).

Table 1. Field Costs Summary for KKC Alternatives

Item	North Tunnel Alignment		South Tunnel Alignment	
	Option A	Option B	Option A	Option B
Contract Cost[1]	$164,319,000	$164,243,000	$189,212,000	$189,138,000
Subtotal with Contingencyt[2]	$205,399,000	$205,304,000	$236,515,000	$236,423,000
Field Cost[3]	$217,600,000	$217,500,000	$250,500,000	$250,400,000

1. Contract Cost includes labor, materials, equipment, subcontractors, and contractor markups.
2. Subtotal includes 25% contingency.
3. Field Costs have been rounded up to the nearest $100,000. Field Costs include a range of -20% to +40% as presented in Section 17.0.

1.8 Comparison of Alternatives

Table 2 presents a summary table of the basic project characteristics and a discussion of relative advantages and disadvantages of the North and South Alignments.

Table 2. Comparison Summary of KKC Alternatives

Characteristic	North Tunnel Alignment	South Tunnel Alignment	Advantages/Disadvantages
Diversion and Intake	Yakima River diversion and intake		The Yakima River diversion and intake is the same for both alternatives.
Conveyance from Keechelus Dam Outlet Channel to Keechelus Portal	Option A (1,440-foot pipeline) Option B (1,200-foot tunnel)		Options A and B are the same for both alternatives. Option A (pipeline) appears to be the lowest construction cost and would most likely involve less construction risk than Option B (tunnel).
Keechelus Portal	130' deep, 25' diameter shaft		The same for both alternatives.
Deep Tunnel Length	21,390-foot-long	9,310' long (Seg A) 16,770' long (Seg B)	The South Tunnel is approximately 4,700-feet longer than the North Tunnel.
Intermediate Portal	None	Adjacent 25-foot-diameter shafts near I-90 Exit 62	The South Tunnel requires intermediate I-90 Exit 62 portals which could allow concurrent tunnel mining in two directions. Intermediate portals may also provide an advantage for tunnel ventilation.
Deep Tunnel Excavation	From at grade Kachess Road portal	From I-90 Exit 62 deep portal shafts	Kachess Road portal provides the advantage of an at-grade access to the tunnel and for muck removal. The I-90 Exit 62 portal could provide the advantage of concurrent mining in two directions, but would require muck removal from deep shafts.
Tunnel Unwatering During Construction	Drain by gravity to the Kachess Lake Rd Portal	Require pumping from the I-90 Exit 62 Portal shafts	The North Tunnel would drain by gravity to the at- grade Kachess Lake Rd Portal. The South tunnel would drain by gravity to the Exit 62 portal, but would require pumping from the deep shafts to the surface.
Deep Tunnel Muck Disposal	Haul via Kachess Lake Road to I-90	Adjacent to and direct access to I-90 Exit 62	The North Tunnel would have the disadvantage of adding significant truck traffic to Kachess Lake Road. The South Tunnel has the advantage of limiting muck hauling disposal activities to the area near I-90 Exit 62.
Primary Construction Activities Local Impacts	Keechelus Dam area and the Kachess Road portal	Keechelus Dam area and the I-90 Exit 62 portal	The South Tunnel has the advantage of locating most of the tunnel mining construction activities in an already disturbed area next to I-90 Exit 62. North Tunnel construction activities around the Kachess Lake Road portal would require temporary relocation of Kachess Lake Road during construction and result in some disruption of local traffic to the Kachess Reservoir campground.
Hydraulics	Uniform gravity free flow	Gravity and pressure flow	The North Tunnel provides the advantage of a uniform gravity free flow for its entire length. The South Tunnel would be a combination of gravity free flow (Segment A) and pressurized flow (Segment B) hydraulics with an intermediate drop shaft.

Characteristic	North Tunnel Alignment	South Tunnel Alignment	Advantages/Disadvantages
Kachess Discharge Structure	Drop structure, box culvert and spillway	Cut and cover pipeline to discharge structure	The North Tunnel discharge system is more complex and visible than the South Tunnel discharge structure.
Geotechnical	Deeper tunnel alignment	Shallower tunnel alignment	There is limited geotechnical information available for both alternatives. More information will be required to determine any specific advantages or disadvantages for either alignment.
Estimated Field Costs ($million)	$127 to $227	$148 to $263	Based upon currently available information, the North Tunnel is approximately between $21 million and $36 million (15%) less in field cost than the South Tunnel.
Operations and Maintenance	Most operational activities will be at the Yakima River diversion and intake		Although the South Tunnel has more complex tunnel hydraulics, most of the system operations and maintenance for both alternatives will occur at the Yakima River diversion and intake.

2.0 Project Purpose

This Feasibility Design Report describes project alternatives and technical considerations to convey water from Keechelus Reservoir to Kachess Reservoir as part of the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan). This report and many of the associated technical memoranda were prepared by a project team led by HDR Engineering, working in close collaboration with Reclamation staff at the Columbia-Cascades Area Office in Yakima, WA and Technical Services Center in Denver, CO.

The purpose of the Keechelus-to-Kachess Conveyance (KKC) 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 in order to provide benefits to fish and wildlife, particularly Chinook and steelhead. In the event that the separate Kachess Drought Relief Pumping Plant (KDRPP) is constructed, an additional purpose of the KKC project is to accelerate refill of Kachess Reservoir in years following pumping by KDRPP.

The goals of the Integrated Plan are as follows: to protect, mitigate, and enhance fish and wildlife habitat; to provide increased operational flexibility to manage instream flows to meet ecological objectives; and to improve the reliability of the water supply for irrigation, municipal supply, and domestic uses.

The KKC project is located east of Snoqualmie Pass along Interstate-90 (I-90) approximately 20 miles northwest of Cle Elum, Washington (Figure 1).

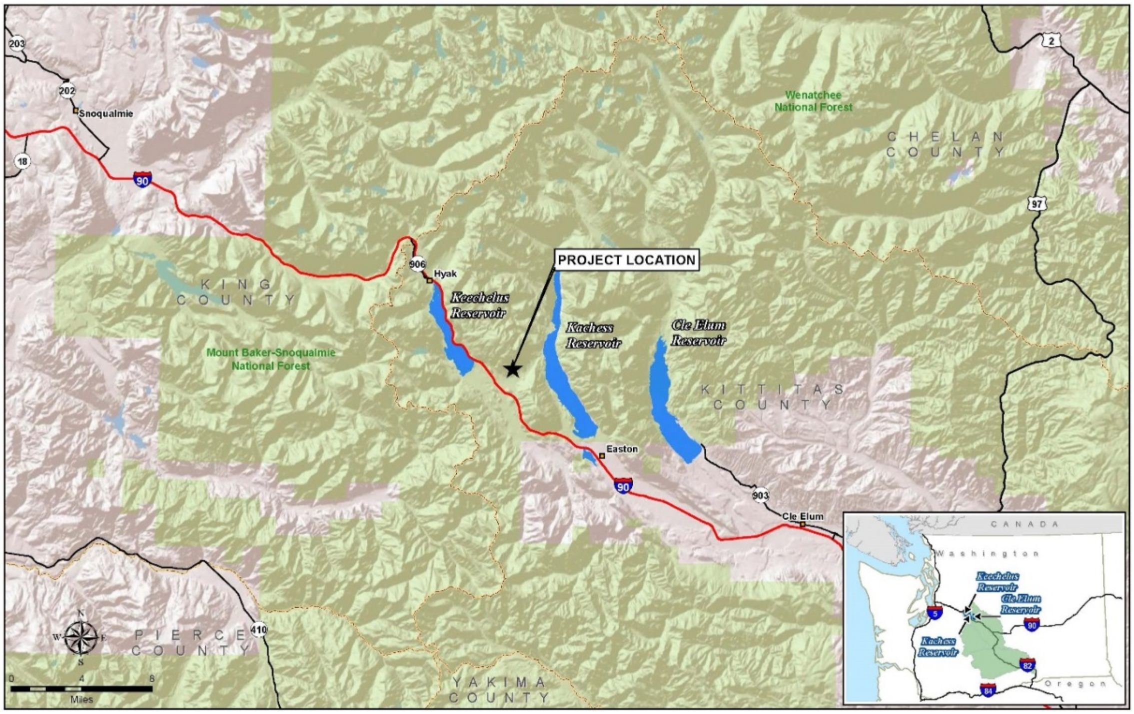

Figure 1. KKC Conveyance Project Location

Transferring water from Keechelus to Kachess Reservoir would improve rearing conditions for steelhead and spring Chinook by reducing high regulated summer flows in the Yakima River between Keechelus Dam and the mouth of the Kachess River (to Lake Easton). Currently, the flows are higher than natural conditions during summer months when Reclamation releases water 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 in most years. The increased reservoir levels would improve bull trout passage to tributary streams currently impaired by low reservoir levels. Increased flow released from Kachess Reservoir would improve instream flow and habitat quality for salmonids in areas downstream of the reservoir.

3.0 Project Description

Figure 2 shows the Keechelus-to-Kachess tunnel alternatives that Reclamation identified as a result of the Value Planning Analysis study (Reclamation, 2014). Appendices A and B include the feasibility design drawings which show more details of the tunnel alternative plans and profiles and project features. All elevations shown on this report and profile views on drawings are in North American Vertical Datum (NAVD) 88 vertical datum.

There are two alternative tunnel alignments proposed from the Keechelus Reservoir to the Kachess Reservoir: the North Tunnel Alignment and the South Tunnel Alignment. Refer to Section 12 for more description of the individual project components.

3.1 North Tunnel Alignment

The North Tunnel Alignment Alternative would divert water from the Keechelus Dam outlet channel to the Yakima River. This alternative would include the following project elements:

- Yakima River diversion and intake, including fish screens.
- Conveyance from the Yakima River intake to the nearby Keechelus portal.
- Keechelus portal drop shaft and plunge pool.
- Deep tunnel from the Keechelus portal to the Kachess Road portal. The tunnel would be 10-foot diameter, concrete lined, and mined up slope from an at-grade Kachess portal to the Keechelus portal drop shaft.
- Kachess Road portal and discharge structure into Kachess Reservoir.
- In the North Tunnel Alignment, the deep tunnel is approximately 21,390 feet long (4.1 miles).

3.2 South Tunnel Alignment

The South Tunnel Alignment consists of two tunnel segments excavated from a portal shaft located in a construction staging area next to I-90 at Exit 62. Tunnel Segment A would be mined up gradient toward the same Keechelus portal drop shaft as described for the North Tunnel Alignment. Workers would mine Tunnel Segment B up gradient northeast to a discharge structure at the Kachess Reservoir shoreline.

Several project elements located in the Keechelus Dam area would be the same as proposed for the North Tunnel Alignment (Section 3.1). These include:

- Yakima River diversion and intake, including fish screens.
- Conveyance from the Yakima River intake to the Keechelus portal.
- Keechelus portal drop shaft and plunge pool.

Additional project elements required for the South Tunnel Alignment include:

- I-90 Exit 62 portal.
- Deep tunnel mined up gradient from the I-90 Exit 62 portal to the Keechelus portal (Segment A).
- Deep tunnel mined up gradient from the I-90 Exit 62 portal to the Kachess Reservoir discharge portal (Segment B).
- Kachess Reservoir portal and discharge structure. (The Kachess Reservoir portal is different from the Kachess Road portal that is part of the North Tunnel Alignment.)

In the South Tunnel Alignment, Segment A of the deep tunnel is approximately 9,320 feet long, and Segment B of the deep tunnel is approximately 16,770 feet long, for a combined length of approximately 26,090 feet (4.9 miles). Both segments would be 10-foot diameter and concrete lined.

3.3 Conveyance from Intake to Keechelus Portal

Under each of the alternatives described above, a 96-inch diameter pipeline or tunnel would convey water from the Yakima River intake to the nearby Keechelus portal. There are two different options for constructing and aligning this pipeline, Options A and B. Option A and B are the same for both the North Tunnel Alignment or South Tunnel Alignment alternatives.

3.3.1 Option A

Option A would be to construct an approximately 1,440 foot-long conventional open-cut-and-cover pipeline from the Yakima River intake structure to the Keechelus portal. The pipeline would skirt the wetland area below the dam and follow the lowest topographic elevations to reduce the depth of excavation required. To reduce streamside impact, the contractor could construct 250 feet of this pipeline through the embankment next to the river using a trenchless method such as pipe ramming. The total length of this option would be 1,440 feet.

3.3.2 Option B

Option B would be to construct a 1,200-foot-long shallow tunnel from the Keechelus portal to the Yakima River intake structure. Construction of the tunnel would utilize trenchless installation methods, such as bore and jack. Option B would utilize the Keechelus portal excavation as the launch point of the tunneling equipment for the pipeline. This would require a larger Keechelus portal shaft than Option A to accommodate the additional use of the shaft excavation.

3.4 Combinations of Alternatives

Reclamation has identified four overall combinations of alternatives, using the two different tunnel alignments (North and South) and the two different conveyance options near Keechelus Reservoir (Options A and B). The four combinations are listed below:

- North Tunnel Alignment – Option A.
- North Tunnel Alignment – Option B.
- South Tunnel Alignment – Option A.
- South Tunnel Alignment – Option B.

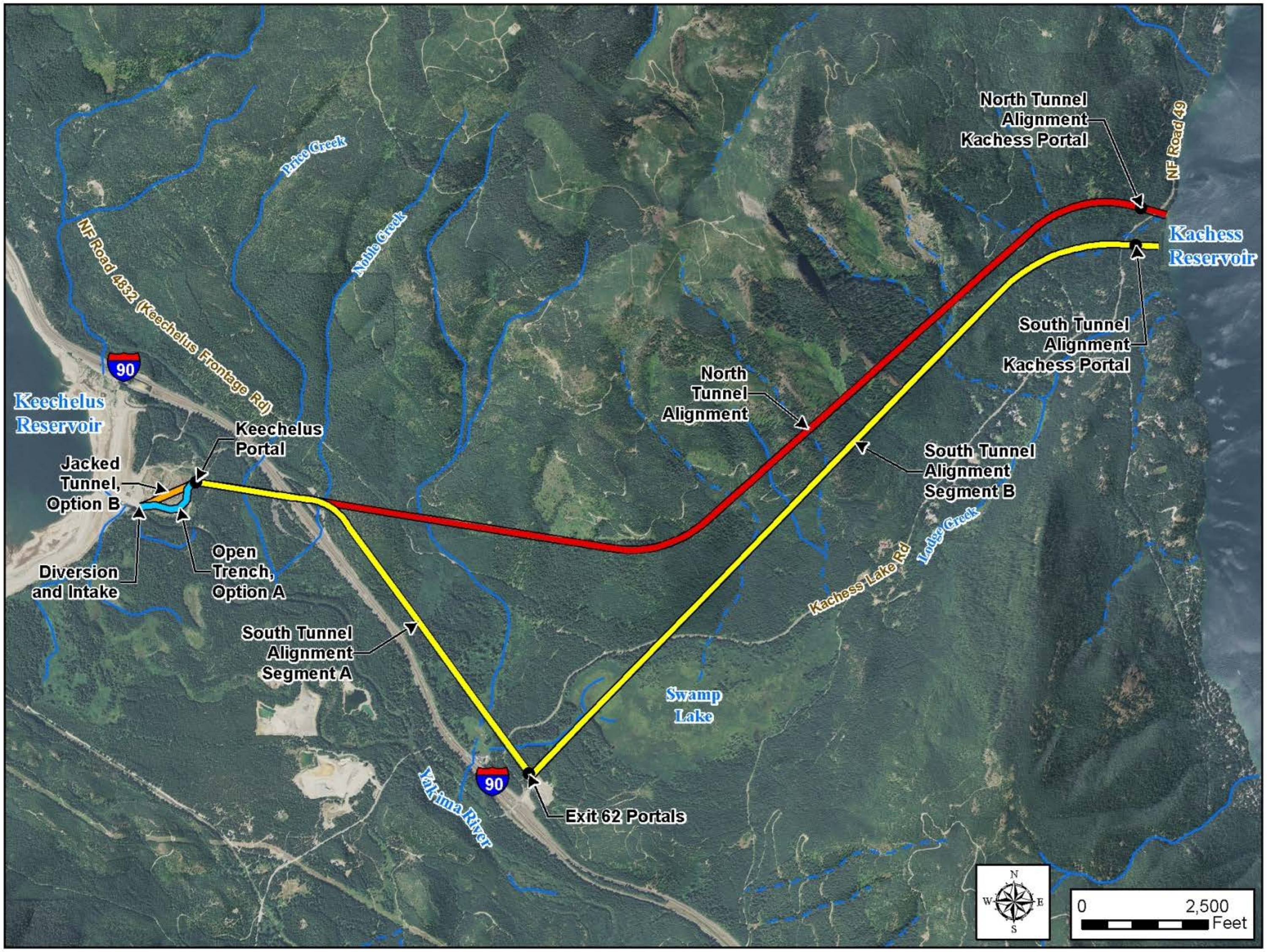

Figure 2. Keechelus-to-Kachess Alternative Alignments

4.0 Existing Facilities

All of the existing Reclamation facilities associated with this project are located in the Keechelus Dam area. The project would affect the following existing facilities:

- The east end of the riprap-lined outlet channel below Keechelus Dam.
- The Yakima River gauging station, which would have to be relocated immediately downstream of the existing site.
- Existing three-phase power will be extended to provide power to the new facilities.

The KKC project would not modify or affect Keechelus Dam itself. Other nonaffected facilities at the site include dam operations buildings and recreational vehicle pads located north of the outlet channel. Figure 3 shows the locations of existing facilities in the Keechelus Dam area.

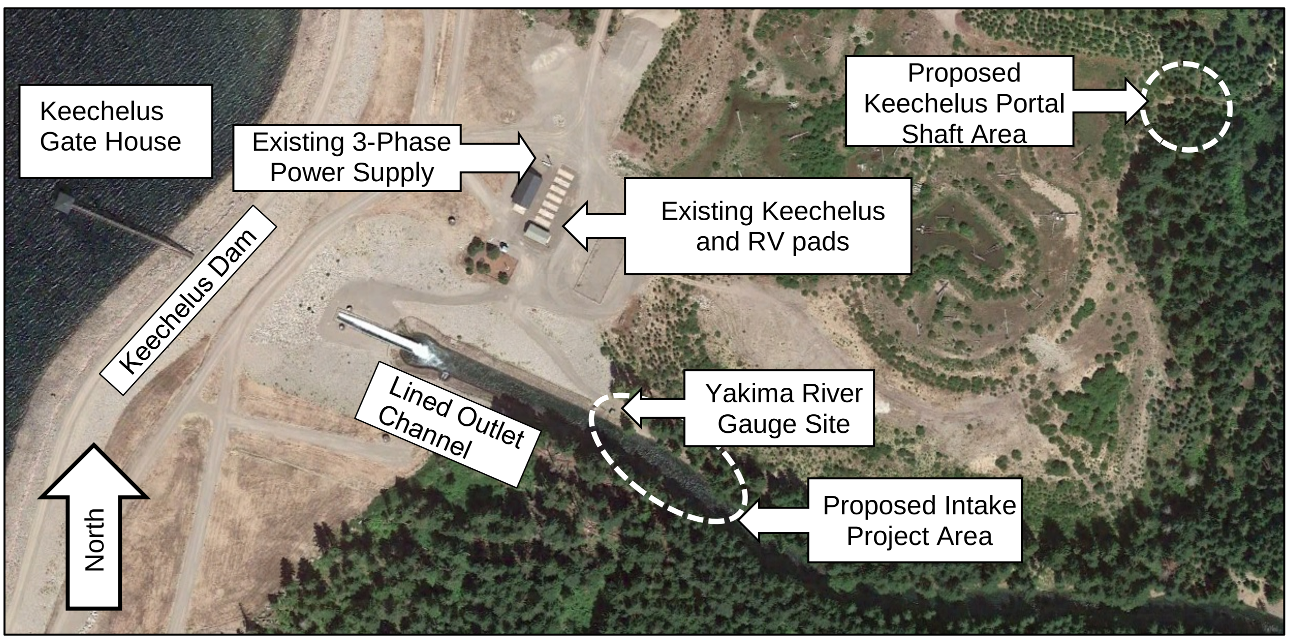

Figure 3. Existing Keechelus Area Facilities

5.0 Prior Studies

The KKC project is currently at a feasibility stage of development. Previous technical memoranda described initial project criteria and a pipeline alternative (Reclamation and Ecology, 2011a); screening of alternatives (Reclamation and Ecology, 2013); value analysis of alternatives (Reclamation, 2014); interpretation of geotechnical conditions (Reclamation and Ecology, 2014d); hydraulics review (Reclamation and Ecology, 2014e); the project design criteria (Reclamation and Ecology, 2014b); and field cost estimates (Reclamation and Ecology, 2014c). The project team has also performed hydrologic analysis of the Yakima River system to evaluate project performance and establish the appropriate capacity for the KKC project (Reclamation and Ecology, 2014a). These technical memoranda provide information that is more specific and details related to the alternatives and project elements described in this Feasibility Design Report.

These prior studies looked at a number of different gravity flow pipeline and tunnel alternatives. These early alternatives included several different Keechelus area diversion and intake locations as well as different pipeline and tunnel alignments and discharge locations and configurations. The project team compared and refined these alternatives, which resulted in the final alternatives that are described in this Feasibility Design Report.

HDR subcontracted Shannon & Wilson, Inc. in 2013 to perform geological and geotechnical investigations for the KKC project. These investigations included geologic mapping, exploration drilling, instrumentation installation, laboratory testing, field hydraulic conductivity testing, and downhole geophysical surveys. The results of these investigations are presented in the Shannon & Wilson, Inc. Geotechnical Data Report (Shannon & Wilson, 2014).

Reclamation is currently undertaking additional geotechnical exploration, testing, and reporting starting with two new borings during the fall of 2014. The exploration program will then be resumed with additional borings and testing beginning in the spring of 2015. The findings of those additional explorations, testing, and reporting will be used to refine the design of the selected alternative.

6.0 Climate

The project area is located in the Cascade Mountains at elevations between 2,440 and 2,300 feet above sea level. Table 3 shows the typical weather in the Keechelus Reservoir area, based upon the available summarized period of record from Reclamation Hydromet and NOAA for temperature and rainfall and the Western Regional Climate Center for snow.

Although the snowfall data is a bit dated, the general trends are still consistent with the current pattern of typical monthly snowfall in the project area. Snowfall typically occurs during the months of November through April. Peak rainfall months are typically in October and early November before precipitation begins falling more as snow in late November.

Table 3. Typical Weather at Keechelus Dam

	Monthly Average for the Period of Record												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg Max. Temp (F)	32.9	37.4	42.4	48.7	57.0	63.7	72.3	73.0	66.9	55.0	40.9	34.0	52.3
Avg Min. Temp (F)	21.2	22.5	25.7	30.0	36.5	43.7	48.4	47.8	41.2	34.6	28.9	23.9	33.9
Avg Total Rain (in.)	11.1	7.7	7.0	4.2	2.8	2.1	1.1	1.3	2.7	6.1	10.2	11.3	67.4
Avg Total Snow (in.)	59.8	41.0	34.0	9.5	0.7	0	0	0	0	1.8	22.5	48.0	217.2
Avg Snow Depth (in.)	41	52	52	29	4	0	0	0	0	0	4	19	17

(Temp/Rainfall data Oct 1908 - Sep 2014 and snow data Jan 1931 - Aug 1977)

7.0 Agency Coordination

Reclamation planning and National Environmental Policy Act (NEPA) compliance activities for the KKC project have included extensive coordination with State, Federal and Tribal agencies, and this coordination would continue during the construction phase of the project. Agencies involved would include those listed below:

- United States Forest Service (USFS) – Reclamation would construct project facilities on Federal land within the Okanogan-Wenatchee National Forest administered by USFS. Coordination would be needed to finalize site selection and configurations; minimize and mitigate impacts on forest resources and recreational users; and to coordinate construction and permanent access and traffic considerations. Reclamation may need to site spoils disposal areas on land within the national forest and this would require coordination with USFS. Following construction, restoration of vegetation on disturbed areas outside the permanent project footprint would require coordination and compliance with USFS requirements.
- United States Fish and Wildlife Service (Service) – Reclamation would coordinate with the Service, including achieving consistency with the Fish and Wildlife Coordination Act report developed for the Integrated Plan. In addition, Reclamation will consult with the Service on Endangered Species Act to determine effects on threatened and endangered species.
- National Marine Fisheries Service (NMFS) – Reclamation would consult with NMFS on Endangered Species Act to determine effects on threatened and endangered species..
- Corps of Engineers – Reclamation will obtain permits for construction.
- Yakama Nation – Reclamation would coordinate with the Yakama Nation on water supply, fish and cultural considerations Washington State Department of Fish and Wildlife (WDFW) – Reclamation would coordinate with WDFW including obtaining permits for construction and operations for the KKC project.
- Washington State Department of Ecology – Ecology is a partner with Reclamation in funding and leading development of the Integrated Plan and its various projects, including the KKC project. Reclamation would coordinate with Ecology's Office of Columbia River, which manages the agency's activities in this regard. Reclamation will also coordinate with Ecology's Water Quality Program related to protection of water quality during project construction.
- Washington State Department of Transportation (WSDOT) – Interstated-90 (I-90) lies immediately adjacent to the Keechelus Dam area, and the KKC tunnel (both alignments) would pass beneath the highway. Reclamation would coordinate with WSDOT in planning for the passage beneath the freeway; and for traffic management issues that may arise in connection with construction activity and use of the highway for workers, materials, equipment, and spoils transportation.

- Washington Department of Archeology and Historic Preservation – Reclamation will consult with DAHP to determine whether the project would impact historic or cultural resources.
- Kittitas County and local cities – Reclamation would inform Kittitas County, and the Cities of Easton, Cle Elum and Ellensburg of construction planning and construction progress, to enable these cities and the county to anticipate and respond to impacts or needs affected by the project.
- Irrigation Districts served by water from the Yakima Irrigation Project – Reclamation would inform irrigation districts that have Federal contracts of construction planning and construction progress. In general, Reclamation does not expect construction to affect irrigation districts, unless special provisions need to be made for drawdown of Kachess Reservoir to accommodate construction of the KKC tunnel outlet works in the reservoir.

In addition to overall coordination activities, Reclamation or its contractor would need to acquire a number of permits to construct the KKC project. Permitting is discussed in Section 8.0.

8.0 Environmental Considerations

Reclamation and Ecology are preparing a Draft Environmental Impact Statement (DEIS) for the KKC and KDRPP. Reclamation and Ecology are jointly leading and preparing the DEIS as a combined NEPA and State Environmental Policy Act (SEPA) document.

The National Environmental Policy Act of 1969 (40 U.S.C. Section 4321 et seq.) requires that the action agency determine whether or not there are any environmental impacts associated with proposed Federal actions. The action agency must document this evaluation and present it to the public. This is being done in an Environmental Impact Statement (EIS) for this project. Reclamation plans to issue a Record of Decision following completion of a Final EIS. The Record of Decision documents the decision on which alternative, if any, the action agency will implement and reasons for its selection. The Record of Decision completes the NEPA compliance process.

The KKC/KDRPP EIS is currently under development and will evaluate environmental considerations and potential impacts of the project on elements of the environment, such as air, soil, water resources, aesthetic values, cultural resources, wildlife, vegetation, etc. The results of the EIS analysis will inform the final design of the project to mitigate environmental concerns.

To construct the KDRPP and KKC projects, Reclamation and Ecology would obtain all required permits and meet other requirements set forth by law, regulation, ordinance, and policy. Table 4 summarizes the potential permit requirements that have been identified to date.

As a component of the Kachess Drought Relief Pumping Plant (KDRPP) and Keechelus-to-Kachess Conveyance (KKC) projects, Reclamation and Ecology have identified bull trout enhancement projects to address a need for improving the resiliency of bull trout populations in Keechelus and Kachess reservoirs, as well as in the Yakima River Basin as a whole.

Individual projects were developed in conjunction with the U.S. Fish and Wildlife Service (Service), National Marine Fisheries Service (NMFS), Washington Department of Fish and Wildlife (WDFW), and the Yakama Nation.

Specifically, the projects address low abundance, passage barriers, degraded habitat, dewatering and prey base threats for Keechelus and Kachess reservoirs and address a passage barrier threat for the South Fork Tieton population. Passage barriers created by drawdowns of Keechelus and Kachess reservoirs are addressed through Reclamation's mitigation responsibilities. Bull trout enhancement projects include the following:

- Gold Creek Passage and Habitat Improvements
- Gold Creek USFS Bridge Replacement
- Cold Creek Passage Improvements

Table 4. Summary of Potential Permit Requirements and Other Approvals

Agency	Permits and Other Requirements	Jurisdiction/Purpose
Federal Agencies		
Service and NMFS	Endangered Species Act (16 U.S.C. § 1531)	Consultation to determine effects on threatened and endangered species.
NMFS	Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801-1802)	Reclamation required to consult with NMFS on activities that may adversely affect Essential Fish Habitat (EFH) to determine whether the Proposed Action "may adversely affect" designated EFH for relevant commercially, Federally-managed fisheries species within the Proposed Action area.
Service	Fish and Wildlife Coordination Act (16 USC 661066c)	Coordination with the Service on the effects of the project on Federally-listed species.
U.S. Army Corps of Engineers (Corps)	If required, Clean Water Act Section 404 (§ 404, 33 USC § 1251 et seq.)	Potential impacts associated with the discharge of dredged or fill material into Waters of the United States, including wetlands.
State Agencies		
Ecology	Clean Water Act Section 401 (33 USC § 1251 et seq.)	Ecology would issue a Section 401 Water Quality Certification in response to the Corps Section 404 permit.
Ecology	Construction National Pollution Discharge Elimination System (NPDES) (90.48 RCW). Clean Water Act Section 402 (§ 402, 33 USC § 1251 et seq.)	Construction Stormwater General Permit required for construction projects engaged in clearing, grading, and excavating activities that disturb one or more acres.
WDFW	Hydraulic Project Approval (77.55 RCW)	Required for construction projects that use, divert, obstruct, or change the natural bed or flow of State waters.
WDFW	Fish and Wildlife Coordination Act (16 U.S.C. 661066c)	Coordination with WDFW on effects of the project on fish and wildlife species.
Department of Archaeology and Historic Preservation	National Historic Preservation Act (NHPA) (16 U.S.C. § 470 et seq.)	Reclamation and Ecology will complete Section 106 consultation to determine whether the project would impact historic or cultural resources.

Agency	Permits and Other Requirements	Jurisdiction/Purpose
(DAHP)	Governor's Executive Order 05-05	Ecology required to review capital projects with DAHP and affected Tribes; conduct appropriate surveys; and take reasonable actions to avoid, minimize, or mitigate adverse effects to historic properties.
Local Agencies		
Kittitas County	Shoreline Management Program	Required for actions on private lands taking place within the shoreline jurisdiction.
Kittitas County	Critical Areas Ordinance	Required for actions on private lands that affect wetlands and streams.

9.0 Design Criteria

This section provides selected project design criteria from the Design Criteria Technical Memorandum (Reclamation and Ecology, 2014b). For more detailed project design criteria, refer to that technical memorandum.

9.1 KKC Transfer Flow Rate Capacity

Based upon the RiverWare hydrologic modeling analysis conducted in 2014 (Reclamation and Ecology, 2014a) and evaluation of environmental benefits (Reclamation and Ecology, 2012), the KKC flow capacity was set at 400 cubic feet per second (cfs). By transferring water from storage in Keechelus Reservoir to storage in Kachess Reservoir, this flow rate would enable Reclamation to reduce flows in the upper Yakima River to approximately 500 cfs beginning in July each year between Keechelus Dam and Lake Easton (approximately 10.3 river miles). Reclamation's release of water from Keechelus Reservoir is a major contributor of flow in this reach particularly in the dry season of the year when local tributary inflows are very low. Reclamation would then ramp down the flow rate in this reach of the Yakima River from 500 cfs in early August to 120 cfs by early September. In addition, to improve fish habitat conditions in this reach of the Yakima River, the year-round minimum flow in that reach of the river would be 80 to 100 cfs. These are the current instream flow targets.

9.2 Yakima River Diversion Location

The project team considered several alternatives for diverting flow from Keechelus Reservoir to the KKC tunnel, including a new intake in Keechelus Reservoir and connecting directly to the existing outlet tunnel.

After consideration of the alternatives and discussions with the project team, Reclamation selected the location of the Yakima River Diversion just below the existing Keechelus Dam outlet works. This was based upon the following criteria:

- It avoids installing a pipeline and tunnel from a new reservoir outlet through or under Keechelus Dam, which Reclamation determined could be a potential dam safety concern.
- It avoids modifying and connecting to the existing outlet works and gravity flow tunnel through the dam.

- The diversion site is as close to the dam as practical, which maximizes the length of the Yakima River where fish habitat would benefit from the improved instream flow regime discussed above. Approximately 10 miles of fish habitat would benefit.
- The site has relatively close proximity to the proposed Keechelus portal shaft that diverts flow to the KKC tunnel. This minimizes the length of the conveyance pipeline or tunnel needed to transfer water from the Yakima River to the portal shaft.
- The site has room for fish screens and for future fish passage facilities.

9.3 Other Conveyance Criteria

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

- Rely on gravity flow to avoid the cost and operational requirements of pumping water.
- Minimize capital and operations and maintenance costs.
- Minimize negative environmental or public impacts.
- Avoid modifications or impacts on the existing Keechelus Dam and outlet works.

9.4 Reclamation-Preferred Tunnel Design Criteria

Reclamation prefers free-flow, rather than pressurized tunnels because they avoid having to manage and design for pressure transients and make the tunnels easier to operate, drain, inspect, and maintain. The project team deepened the Keechelus portal shaft (to approximately 135 feet) and flattened the tunnel profiles to maintain open channel flow (free-flow) within the tunnel. Reclamation would use control gates at the Yakima River intake to control the rate of flow into the system. The drop shaft and plunge pool in the Keechelus portal shaft will hydraulically disconnect the system upstream of the Keechelus portal from the main KKC deep tunnel downstream of the Keechelus portal.

Although Reclamation prefers free-flow tunnels, a pressurized tunnel was not ruled out if ground conditions are suitable. The project team obtained other tunnel design criteria from the Reclamation Design Standards (Reclamation, 1994a).

Reclamation will further evaluate the final tunnel configuration during final design after more geotechnical information is available. Table 5 presents Reclamation-preferred tunnel criteria for tunnel design as discussed and provided by Reclamation Technical Service Center (TSC) personnel.

Table 5. Reclamation-Preferred Tunnel Design Criteria

Criteria	Reclamation Preference
Hydraulic design (pressurized vs. free-flow)	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 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 or 1.5 feet freeboard, whichever is greater.
Lining	Varies - shotcrete, reinforced concrete, or precast segments; pressurized tunnels may require steel lining at higher pressures or near the entrance, or both, depending upon rock quality, permeability, and modulus of deformation.

Tunnel hydraulics design criteria also reference Reclamation Design Standards for General Hydraulic Considerations (Reclamation, 1994b) and are discussed in more detail in the Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e).

9.4.1 Infiltration and Exfiltration Rate

The tunnel design should minimize infiltration and exfiltration. The maximum infiltration and exfiltration rate would be 100 gallons per day, per inch-diameter, per mile of tunnel. Another way of stating this is a rounded up rate of 19 gallons per day per inch-diameter per 1,000 feet of tunnel. The North and South Tunnel Alignment alternatives have a nominal boring diameter of 12 feet with an internal finish diameter of 10 feet. Table 6 shows calculated maximum infiltration or exfiltration volumes.

Table 6. Maximum Infiltration and Exfiltration Rate

Criteria	Length And Diameter	Maximum Rate (gpd)
Option B: Keechelus Jacked Tunnel	1,200 feet, 96 inches	2,200
North Tunnel Alignment: Kachess Portal Tunnel	21,390 feet, 12 feet	58,000
South Tunnel Alignment: I-90 Portal Tunnel	26,120 feet, 12 feet	72,500

Currently, there is not enough geotechnical information available to determine probable infiltration and exfiltration rates, so the project team assumes for cost estimating purposes that the tunnel would need to be concrete lined.

9.4.2 Gravity Tunnel Criteria

The project team has designed the systems for the North and South Tunnel Alignment alternatives to convey 400 cfs during flow transfer operation. For the two alternatives, the analysis 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 a contractor would mine using a road header or drill and blast method, or both. In either case, it is likely, depending upon the rock quality encountered, that portions of the tunnel would need to be lined or rock bolted for stability. For the purposes of the feasibility design, the project team has assumed a TBM-mined circular tunnel will be constructed.

A circular tunnel would be a 12-foot-diameter boring with a 10-foot inside diameter. The project team selected this diameter for both hydraulic capacity and tunnel construction logistics. This diameter is the approximate minimum size that would be required for tunnels of this length to allow for efficient personnel and equipment access, muck removal, and electrical and ventilation support systems. In this long reach, the contractor may decide to install a set of parallel tracks in enlarged sections of the tunnel to facilitate muck handling by allowing muck trains to pass going in opposite directions.

9.4.3 Tunnel Lining Assumptions

There is limited geotechnical information available regarding the rock quality for the North Tunnel Alignment and no information available for the South Tunnel Alignment; however, based upon local geology, it was assumed that the full length of tunnel between the Keechelus portal and the Kachess portal would be in rock. This assumption needs to be verified with additional geotechnical exploration. Depending upon the depth to and competency of the rock, the South Tunnel Alignment profile could either be modified or soft ground tunneling could be consideration for parts of the alignment.

Hydraulics and cost estimating were based on the assumption that the entire length of the 12-foot-diameter bored tunnel would require some measure of rock support and that the entire tunnel would be concrete lined to the 10-foot inside diameter.

The tunnel for either alternative would be lined with one of four rock support classes. See Section 13.6.1 for descriptions of the rock support classes. Refer to the Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) for details regarding the tunnel lining assumptions. See Appendices A and B for drawings of the typical tunnel support classes and lining.

9.4.4 Tunnel Ventilation

The contractor would need to ventilate the tunnel with temporary, powered ventilation systems during construction. The ventilation system would consist of electrical blowers and temporary supply air ducting that would be suspended within the tunnel and extended to follow along behind the TBM as the contractor mines the tunnel.

The ventilation requirements will be determined in more detail in the next phase of design, but it may be necessary to enlarge the longer North Tunnel Alignment tunnel bore diameter to 13 feet to allow for the installation of larger ventilation ducting and intermediate air blower stations to convey fresh air to the TBM end of the tunnel bore. Another perhaps more technically challenging and difficult option could be to install an intermediate approximately 4 to 6 foot finish diameter ventilation shaft approximately half way along the alignment. The technical challenge with this option would be to size the shaft so that it can be accurately constructed and aligned to intersect with the deep tunnel. To minimize ground disturbance, this intermediate shaft could be constructed from an area adjacent to one of the existing USFS roads that cross over the tunnel alignment.

To account for the additional North Tunnel Alignment ventilation requirements, the cost estimate assumes that the tunnel diameter would be oversized to 13 feet.

The contractor would remove temporary air systems used during construction after construction has been completed. For permanent operations, inspectors would need to use portable ventilation systems and/or personal air packs to perform occasional tunnel inspection and maintenance activities.

All temporary construction ventilation systems and future portable inspection ventilation systems and personal air packs would have to comply with Reclamation Safety and Health Standards.

9.4.5 Tunnel Lighting

The contractor would install temporary electrical lighting and extend it behind the TBM as the contractor mines and lines the tunnel. The lighting would be powered by either connecting to the local electrical grid or by a temporary power generator system at the tunnel-mining portal. The contractor would remove these temporary lighting systems after construction. The design does not include any permanent lighting in the tunnel but does include permanent lighting in the upper part of the tunnel access shafts and surface lighting of the shaft area.

9.5 Fish Screening Criteria

For fish screening criteria, the project team conformed to criteria in the NMFS Northwest Region report, "Anadromous Salmonid Passage and Facility Design" (NMFS, 2011). The project team used the following design criteria:

1. The maximum approach velocity would not exceed 0.40 fps for inriver intakes.
2. The minimum sweeping velocity would be at least 0.80 fps.
3. The screen face was selected as inclined to match the side slope of the existing engineered channel, which is approximately 1.5 horizontal-to-1 vertical. Baffles would be used behind the fish screens to adjust and maintain uniform velocity flows through the fish screens.
4. The slotted rectangular screen face openings would not exceed 1.75 millimeters (mm) (0.07 inch) in the narrowest direction and have a minimum percent open area for the screen material of at least 27 percent.
5. Baffles behind the screens would be used to adjust and maintain uniform velocity flows through the fish screens.
6. All metal materials below the water surface elevation would be stainless steel type 304L.
7. All new diversion structure surfaces potentially exposed to fish would be smooth and have no sharp edges or burrs that could injure fish.

8. The fish screens would have an automated airburst cleaning system for both cleaning debris and controlling ice buildup on the screens.

9.6 Fish Downstream Bypass

There currently are no fish passage facilities at Keechelus Dam. As part of Reclamation's Storage Dam Fish Passage Study and the Yakima Integrated Plan fish passage element fish passage at Keechelus has been reviewed at a conceptual level. In order to ensure compatibility in the location of infrastructure associated with KKC and adult/juvenile fish passage facilities, HDR has provided preliminary fish passage designs to layout basic future fish passage facilities at Keechelus Dam.

Future adult (upstream) and juvenile (downstream) fish passage criteria and alternatives are discussed in more detail in the Keechelus and Kachess Dams Fish Passage Concepts Review Technical Memorandum (Reclamation and Ecology, 2014f).

An adjustable crest dam apron design provides a barrier to upstream fish migration so that Yakima River fish do not get into the 400-foot-long reach of lined Keechelus Dam outlet channel above the new diversion dam. The screen and intake facility design would accommodate future installation of a fish trap-and-haul facility.

This section briefly discusses fish passage criteria and future fish passage facilities.

9.6.1 Fish Bypass Criteria

Reclamation would install one section if the future fish passage ladder section as part of this project to facilitate downstream bypassing of fish through the existing Keechelus Dam outlet. This fish ladder segment would be designed so that it could be connected to the future fish passage ladder segments that would convey fish to a future trap-and-haul facility.

The project team used a minimum instream flow of 80 cfs for the fish bypass design flow. This is 20 percent of the maximum diversion flow of 400 cfs. The fish bypass would have a hydraulic capacity of 20 cfs. For future trap-and-haul operations, the fish ladder would have the ability to provide an additional auxiliary attraction flow of up to 50 cfs at the downstream fish ladder entrance. Since Reclamation would control the water surface of the forebay to the fish bypass with the adjustable crest dam, the fish bypass would be a pool and weir fish ladder. Each pool would be 8 feet long by 6 feet wide by 5 feet deep and would have a 0.75-foot drop.

9.6.2 Future Fish Passage Facilities

In 2001, Reclamation committed to study the feasibility of fish passage at all five storage dams of the Yakima Project and to seek funding to implement passage where determined feasible. Reclamation's commitment is documented in mitigation and settlement agreements and permits associated with the Keechelus Dam Safety of Dams (SOD) Modification. As a result of these agreements and permits, Reclamation completed a *Phase I Assessment Report* of all five dams in 2003, updated in 2005. This report highlighted Cle Elum and Bumping Lake Dams as high-priority sites for continued investigation.

Future evaluation of passage at the remaining four dams, including Bumping Lake Dam, would require additional study funds, including firm cost-share commitments from other agencies. The intent, to the extent possible, is to meet all of the essential Keechelus Dam SOD requirements outlined in the Record of Decision, the Washington State Hydraulic Project Approval permit, the Mitigation Agreement between the Washington Department of Fish and Wildlife (WDFW) and Reclamation, and the Settlement Agreement between Reclamation and Yakama Nation.

The drawings included in Appendix C show the potential layout for a future fish trap and haul fish passage facility. The future fish passage facility would include an extension of the fish ladder, a crowder tank, an overhead crane, and holding tanks. The location of the future fish passage facility is shaded on the drawings to distinguish this future facility from the currently designed facilities.

9.7 Potential for Hydropower Generation

The project team evaluated the potential for generating hydropower from the KKC transfer and deemed it infeasible for the following reasons:

- Reclamation would operate the facility only during periods 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 surge mitigation facilities (surge tower, controls, or valves) to allow for the dynamic surge conditions that could occur under hydropower operations would add cost to the tunnel.
- 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, Reclamation would need to perform continuous and ongoing maintenance of the mechanical and electrical components of the hydropower facility.

Because of these issues, the cost of the hydropower facility would likely be about two-to-three times higher than economically feasible based upon the potential benefits. Therefore, the project team did not consider hydropower generation as a design criterion.

10.0 Operating Criteria

This summary discussion is excerpted from the Hydrologic Modeling of System Improvements, Phase 1 Report (Reclamation and Ecology, 2014a). A more detailed explanation of the modeling and development of the KKC operating criteria is contained within that report.

10.1 KKC Operating Rules

One primary purpose of the proposed KKC project is to improve instream flows and habitat conditions within the Keechelus Reach (between Keechelus Dam and Easton) of the Yakima River. In certain conditions, there may also be slight water supply benefits to the project (by transferring some of the larger runoff relative to reservoir storage capacity associated with the Keechelus Reservoir watershed), but these are secondary. Also, when KKC is combined with KDRPP, the tunnel helps refill Kachess Reservoir more quickly, avoiding reservoir drawdown impacts to fish in that reservoir.

The delivery of water stored in Keechelus to meet water supply needs during the late summer has an adverse effect on fish-rearing conditions in the Keechelus Reach of the Yakima River. Currently, flows are too high from July through early September when juvenile Chinook and steelhead (and potentially coho, if reestablished) are rearing in this reach. Juvenile salmon seek protection against high-velocity flows to avoid being pushed downstream into less desirable habitat and to minimize energy expenditures. High summer flows cause higher velocities that reduce the amount of suitable rearing habitat for these species. The negative effects on rearing juvenile salmonids from high summer flow conditions in this reach occur during all water years but are most significant in wet years. Flows in summer during a wet year, such as 2002, average about 1,000 cfs and have been as high as 1,300 cfs in recent years.

The KKC capacity was selected to be 400 cfs to meet the following recommended Yakima River flows as derived from flow objectives for the Keechelus Reach listed in the Integrated Plan:

- Reduce flows in Keechelus Reach to 500 cfs during July (key metric).
- Ramp flows down from 500 cfs on August 1 to 120 cfs the first week of September (key metric).
- Increase the base flow to 120 cfs year-round (evaluated at 100 cfs, until the Wymer Dam project is included).
- Provide one pulse flow (500 cfs peak) in early April (not evaluated).
- In drought years, provide an additional pulse of 500 cfs in early May (not evaluated).

10.2 Keechelus Reservoir Storage

The Keechelus target storage above which water is transferred into Kachess is critically important to maximizing the benefit to Keechelus Reach in terms of reducing summer high flows, while avoiding drawing Keechelus Reservoir down so low that adverse up-migration impacts occur to bull trout in the reservoir. Establishing a target storage is not, however, a permanent decision, in that it does not involve a physical structure. For this reason, the Keechelus target storage could be modified in an adaptive fashion in the future. Nevertheless, the target would affect the amount of water that is transferred through the KKC tunnel.

The Keechelus Reservoir target storage was set at 80,000 acre-feet. This value was established for modeling purposes only to protect Keechelus Reservoir from excessive drawdown, while providing significant benefits to Keechelus Reach summer flows. As mentioned previously, the Keechelus target storage can be modified in the future, based upon adaptive management or experience gained in the operation of the Integrated Plan facilities.

11.0 Reclamation Design Standards

The project team used the following Reclamation Design Standards during the Feasibility Study and in preparing this report:

- Bureau of Reclamation (U.S. Department of the Interior), 1994. "Design Standards No. 3, Water Conveyance Systems." Prepared by the Reclamation Technical Service Center, Denver, CO.
    - Chapter 4 Tunnels, Shafts, and Caverns.
    - Chapter 11 General Hydraulic Considerations.
    - Chapter 12 General Structural Considerations.
- Bureau of Reclamation (U.S. Department of the Interior), 2008. "General Guidelines for Preparation of Feasibility Design Reports." Prepared by the Reclamation Technical Service Center, Denver, CO.

12.0 Description of Proposed Facilities

12.1 Keechlus Dam Area Facilities

All of the Keechelus Dam area facilities are common to both the North and South Tunnel Alignment alternatives. The Keechelus Dam area facilities include the following:

- Yakima River adjustable crest diversion dam
- Yakima River fish screens
- Yakima River intake
- Electrical and mechanical systems control building
- Flow measurement facilities
- Electrical power supply
- Conveyance from the intake to the Keechelus portal shaft
- Keechelus portal shaft

12.2 Yakima River Diversion and Intake Location

The KKC Yakima River diversion and intake structure is located as far upstream (close to the dam outlet channel) as possible to maximize the length of Yakima River receiving the benefits of diverting flow from the river during high flow releases from Keechelus Dam. The design locates the intake structure near the end of the lined trapezoidal outlet channel and spillway immediately below the Keechelus Dam. The Keechelus Dam as-built drawings describe this channel as having a 20-foot-wide bottom and 1.5H-to-1V sloped sides. The as-built drawings describe the channel surface as being built with two-foot-thick “grouted riprap."

12.3 Adjustable Crest Diversion Dam

The grouted riprap channel downstream of the Keechelus outlet works is approximately 400 feet long with a slope of approximately 0.5 percent. Reclamation would install an adjustable crest diversion dam just downstream of the intake to maintain the water level in the existing channel so that it can be diverted through inclined fish screens and into the intake structure. A concrete apron below the diversion dam would serve as a hydraulic velocity barrier to prevent downstream fish from approaching and attempting to jump over the dam.

There are several options for adjustable crest dams, including inflatable bladders and hydraulic hinged crest gates. The feasibility level design assumes that an inflatable bladder dam would be used.

Reclamation would raise and lower the dam to preset elevations depending upon the Keechelus flow release and the desired rate of diversion flow from Keechelus to Kachess. Controls and air compressors would be housed in a small building adjacent to the dam.

More detailed drawings of the diversion dam are shown in Appendices A and B.

12.4 Fish Screens

To minimize impacts on this spawning reach and to stay away from the dam, the water diversion would be located at the downstream end of the grouted riprap channel, before entering the Yakima River. The project team designed this water diversion to meet NMFS fisheries criteria.

Appendices A and B show drawings of the fish screens.

The following are the individual screen components:

- Effective Screen Area is 400 cfs divided by 0.4 fps equaling 1,000 square feet, with an added 15 percent screen area to account for structural blinding of the air manifolds behind the screens.
- Required Screen Area is 1,000 square feet plus 15 percent or 1,150 square feet.
- The inclined (rather than the vertical projected) area was used on the basis of the prior approval of this method by the governing fisheries agencies in the Northwest. This design will be further discussed and vetted with these agencies for final approval of the concept during the next phase of design.
- The fish screen shown in Appendices A and B is a Hendrick Screen Profile Bar B6 with a 1.75 mm (0.07 inch) slot opening and a minimum of 37 percent open area. This stainless steel screen material is the most durable flat panel screen material currently available. The screen vertical height would be set to 5.5 feet with the top of the screen 0.5 feet below the water surface to provide choked flow airburst conditions for the screen cleaning system. The height of the screen, given a vertical depth of 5.5 feet and screen slope of 1.5H-to-1V, is 9.92 feet (9 feet, 11 inches), and was rounded to 9 feet, 10 inches (9.83 feet).
- Therefore, the required screen length is 1,150 square feet divided by 9.83 feet equaling 117 feet. This required screen length was divided into four intake bays, each being 29.25 feet long. The left side of the channel bottom would be set an approximate elevation of 2,422 feet (plus or minus 0.50 feet). The bottom of the screen would be set at El. 2,423. Because the project would raise the grouted channel water surface to provide the required submerged screen area, Reclamation would include a fish ladder to provide passage for downstream migrants during periods of diversion operation.

12.5 Yakima River Intake Structure

The design of the intake and fish screen system conforms to the shape and dimensions of the existing lined Keechelus Dam outlet channel. Reclamation would use eight automated and locally- or remotely- operated motorized slide gates behind the fish screens to control the flow into the KKC pipe and tunnel system.

After the water flows through the fish screens, past the baffles, and through the slide gates, it would enter the 12-foot-wide by 16-foot-long intake box. Reclamation would operate the slide gates using the local SCADA control system to maintain flow velocities per fish criteria. The box is shaped to ease the transition of flow into the 96-inch pipeline, which leads to the Keechelus portal shaft. Based on Reclamation's design standards, the pipeline intake would be submerged by at least 1.5 velocity head (Hv) or 3-inches minimum.

The intake structure would also include access hatches, as well as water level and flow rate monitoring equipment. Standpipes at each end of the intake structure would provide air venting of the pipeline.

Table 7 presents intake design criteria. Appendices A and B include intake design drawings.

Table 7. Intake Design Criteria

Criteria	Design
Hydraulic design	Free flow (nonpressurized) open channel flow
Intake box dimensions	12 feet wide by 16 feet long, with a water depth of 7 feet
Inside diameter of pipeline	8 feet
1.5 Hv (velocity head)	1.6 feet
Pipeline invert elevation	El. 2,418

12.6 Electrical and Mechanical Systems Building

An approximately 18-foot-by-30-foot mechanical systems building would house the control system programmable logic control (PLC), SCADA, and local electrical distribution panels; and flow measurement and gate controller systems, compressors, and air receivers for the fish screens and adjustable crest dam.

Like the existing Keechelus Dam building, Reclamation would construct the new building with concrete walls and a standing seam metal roof. The building would contain ventilation, lighting, and remotely monitored fire alarm and security systems.

12.7 Flow Measurment

There is an existing Yakima River flow gauging station located at the end of the lined outlet channel. To measure river flow, this gauging station would have to be located further downstream in a uniform section of the Yakima River below the proposed diversion dam.

This flow measurement data would be transmitted to the diversion system control system PLC located in the electrical and mechanical systems building.

Diverted flow would be measured using a flow meter installed in a straight section of the diversion pipeline between the Yakima River intake and the Keechelus Portal shaft. This flow data would also be translated the control system PLC; which would also combine the river and pipeline flow measurements to provide the total flow coming from the Keechelus Dam outlet.

12.8 Keechelus Area Electrical Power Supply

There is Puget Sound Energy three phase power that serves the existing Keechelus dam area facilities intake, screening, and deep tunnel portal shaft. The project team anticipates that these existing power lines would be extended to provide power to the proposed electrical and mechanical systems building as well as to the motorized gates at the intake.

In the event of a power failure, the control system would maintain the flow settings in place before the power failure occurred. The system would automatically issue an alarm to operational staff. Operators would then respond to the site to make manual adjustments to flow control gates, if needed and then take steps to restore power to the site. Battery backup would provide standby power to alarm, telemetry, and control systems during that period.

The existing Keechelus Dam area facilities include a small propane fueled standby generator to power essential instrumentation and control systems and some emergency lighting. This generator would need to be replaced with a larger (approximately 150 kW) generator to be located in a fenced enclosure adjacent to the existing operations building. It is expected that this generator would also use propane fuel.

12.9 Yakima River to Keechelus Portal Conveyance

This section summarizes the conveyance from the Yakima River diversion and intake to the Keechelus portal shaft. There are two options for constructing and aligning this conveyance, Options A and B. Option A and B are the same for both the North Tunnel Alignment or South Tunnel Alignment alternatives. Appendices A and B includes plan and profile drawings for both conveyance options.

12.9.1 Option A – Cut and Cover Pipeline

Option A is a pipeline that Reclamation would install in a cut-and-cover trench between the Keechelus portal shaft and the Yakima River Diversion and Intake structure. The project team aligned the pipeline to minimize impacts by going around the habitat restoration area that Reclamation installed as part of the dam improvements projects beginning in 2001 and also to avoid, as much as possible, the stand of mature trees east of the habitat restoration area.

Based upon previous Reclamation borings in the area and boring DH-13-5A, which was installed for this project, soils along the pipeline alignment likely consist of silty sand and gravel glacial till-like deposits with cobbles and boulders. A combination of soft-to-hard rhyolite, dacite, and volcanic breccia and tuff rock underlies this area at a varied depth. The contractor would likely support the trench excavation using stacked trench boxes that would be advanced along with the pipe installation. Reclamation would likely require the contractor to bench and lay back the remaining excavation above the trench box, and would determine an appropriate slope based on characteristics of the excavated material and Reclamation Safety and Health Standards.

Reclamation would likely construct the pipeline of either steel or concrete pipe with an inside diameter of 96 inches. The gravity free flow pipeline slope would be designed for a flow of 400 cfs at a maximum velocity of 10 fps.

The first approximately 250 feet of pipeline adjacent to the Yakima River diversion and intake structure would cross under a berm adjacent to the river. The contractor would likely use a trenchless construction method such as pipe ramming because of the depth of excavation required for this segment and its proximity to the river. After the initial 250 feet of pipeline is installed, the contractor would grouted it in place and connect it to the open trenched pipeline.

A flow meter would be located in a 5-foot-diameter meter vault, approximately 275 feet downstream of the intake structure. A PLC would use the flow meter data and real-time water surface elevation measurements to control the KKC flow transfer rate and the instream flow in the Yakima River downstream of the intake structure.

Reclamation will need additional investigative borings prior to final design, possibly including a horizontal pilot boring to provide more information regarding the design. Table 8 summarizes design criteria for Option A.

Table 8. Option A – Cut and Cover Pipeline Design Criteria

Criteria	Design
Hydraulic design	Free flow (nonpressurized) open channel flow pipeline.
Length	1,440 feet including a 250-foot trenchless section.
Inside diameter	8-foot pipeline.
Maximum velocity	10 fps
Slope	- 0.0017

12.9.2 Option B – Shallow Tunnel

Option B is a shallow tunnel that would be bored from a partially excavated Keechelus portal shaft west to the Yakima River diversion and intake structure. Based upon previous Reclamation borings in the area and boring DH-13-5A, which was installed for this project, soils along the tunnel alignment likely consist of silty sand and gravel glacial till-like deposits with cobbles and boulders. With these soil types, and since the average depth of this tunnel is only about 40 feet, the contractor would install the tunnel through the soil material using an open face or main-beam TBM that would be advanced by jacking steel or concrete pipe sections behind the TBM. The open-faced TBM with dewatering in advance of the tunneling operation would allow personnel to access the face to break up and clear obstructions such as boulders. The contractor would grout jacking pipes in place to convey water from the intake structure to the Keechelus portal shaft. The contractor would remove the TBM from the shored and dewatered Yakima River intake structure shaft. Table 9 summarizes design criteria for Option B.

Table 9. Option B – Shallow Tunnel Design Criteria

Criteria	Design
Hydraulic design	Free flow (nonpressurized) open channel flow tunnel.
Length	1,200 feet
Inside diameter	8-foot steel or concrete lining
Maximum velocity	10 fps
Slope	- 0.0017

As in Option A, Reclamation would place a flow meter in a 5-foot-diameter meter vault, approximately 340 feet downstream of the intake structure. A PLC would use the flow meter data and real-time water surface elevation measurements to control the KKC flow transfer rate and the instream flow in the Yakima River downstream of the intake structure.

12.10 North and South Tunnel Alignments – Keechelus Portal Shaft

The Keechelus portal shaft serves several purposes:

- It would connect the shallow Option A Pipeline or Option B Tunnel to the deep tunnel.
- Partially excavated, an elongated section of the shaft would serve as the launching shaft for the shallow Option B tunnel to the Yakima River Intake structure.
- It would be the receiving shaft for the deep North Tunnel Alignment or South Tunnel Alignment tunnels.

12.10.1 Portal Siting

The project team considered the following factors in the location of this portal:

- The location of the shallow pipeline (Option A) or tunnel (Option B) from the Yakima River intake in the alluvial soil.
- The ability to receive the North and South Tunnel Alignment TBM at sufficient depth of cover in rock.
- Provide local access to existing roads while minimizing environmental impacts on the Keechelus Dam wetlands and forested areas.
- Minimize the lengths of the connecting tunnels.

12.10.2 Portal Criteria

It is expected that the portal would be a circular shaft constructed using secant piles through the overburden soil material that were then keyed into the underlying bedrock. The soil material would then be excavated down to bedrock. The rock would then be excavated down to tunnel depth using drill and blast methods. The entire portal shaft would be concrete lined.

Table 10 lists portal design criteria.

Table 10. Keechelus Portal Shaft Design Criteria

Criteria	Design
Option A inside diameter	25 feet
Option B jacking pit inside dimensions	25 feet x 40 feet
Ground surface elevation	2,448
Shallow pipe invert elevation	2,416
Deep tunnel invert elevation	2,330
Plunge pool top of bottom slab elevation	2,320

For Option A the portal shaft would only serve as a receiving portal and the 25-foot-diameter hydraulic diameter is adequate for recovering the tunnel boring equipment. For Option B, the upper soft ground part of the tunnel down to elevation 2,416 would also serve as a jack-and-bore launching shaft. Therefore, for Option B the contractor would need to extend the portal shaft to 40 feet long to accommodate the pipe jacking equipment as well as to allow for dropping in 30-foot pipe sections to be jacked into position.

The water would enter the 128-foot-deep portal through either Option A or Option B and terminate in a 90-degree elbow centered in the shaft. The water would then free fall approximately 84 feet to a 10-foot-deep plunge pool. The water would enter the de-aeration chamber and flow into the deep tunnel. The contractor could use a temporary sump pump to pump water from the plunge pool into the tunnel when the system is not in use.

Other design criteria considerations for the Keechelus portal shaft include the following:

- The open shaft and a separate ventilation pipe from the de-aeration chamber would provide ventilation to release air from the de-aeration chamber and within the tunnel.
- The plunge pool would provide energy dissipation. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) describes the design and depth of the plunge pool.
- The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) describes geotechnical design considerations.

12.10.3 De-aeration Chamber and Plunge Pool Criteria

Once the contractor excavates the portal shaft to the tunnel invert depth, rock drill and blast excavation of the de-aeration chamber could begin. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) discusses the hydraulic design criteria used for sizing the de-aeration chamber. The de-aeration chamber would be reinforced concrete lined, and the end of the de-aeration chamber would contain a bulkhead designed for the deep tunnel TBM to penetrate at the end of the tunneling operation. The contractor would connect the tunnel lining to the end wall of the de-aeration chamber. After the tunneling operation is completed and the TBM has been removed from the shaft, the contractor would excavate the portal shaft to the plunge pool depth, approximately 10 feet below the tunnel invert. The contractor would then line the plunge pool with reinforced concrete tied into the deep shaft and de-aeration chamber concrete lining.

12.10.4 Safety

Reclamation controls site access, so applicable safety standards from the Reclamation Safety and Health Standards manual would be applied during construction and future operation and maintenance activities. The portal top slab would include an access hatch with a permanent ladder only to the intermediate landing. Permanent switchable lighting would be provided for the top part of the portal shaft and landing. The top slab would also have removable concrete access panels to allow for personnel and equipment access into the portal shaft. In accordance with Reclamation Safety and Health Standards, the contractor would likely use a wall rail mounted man-lift system to move personnel from the ground surface to the bottom of the shaft. The contractor may need to provide temporary scaffolding and ladder or stairway access during construction, as well as other safety standards during portal construction, such as temporary fencing and fall protection.

12.10.5 Yakima River Tunnel Receiving Shaft

For either conveyance Option A or B, a 25-foot-diameter shaft would be excavated just behind the Yakima River intake structure to receive either the Option A pipe ram or the Option B tunnel from the Keechelus portal.

12.11 North Tunnel Alignment

The following descriptions apply to the North Tunnel Alignment Alternative.

12.11.1 North Tunnel

To provide for gravity flow of drainage from the tunnel during construction, the North Tunnel Alignment tunnel would be mined upslope from the Kachess Lake Road Portal at the east end to the Keechelus Portal shaft at the west end. To facilitate tunnel access and muck removal, this single segment, 21,390-foot-long tunnel would have an at-grade tunnel entrance at the Kachess Road portal. Based upon this tunnel length and a 12 foot diameter, approximately 90,000 cy of rock would be removed from the tunnel. This volume would increase to 105,000 cy if the tunnel were oversized to 13 feet in diameter to provide room for construction activities and ventilation systems. This alternative would require muck hauling truck traffic for approximately 3.5 miles along Kachess Lake Road before reaching I-90 at Exit 62.

This tunnel alternative was originally conceived and evaluated as a straight alignment from the Keechelus Portal to the Kachess Lake Road Portal; however based on the Value Planning Analysis findings and recommendations, Reclamation determined that the Feasibility Design Report should evaluate a tunnel alignment that is curved in the middle to minimize the depth of overburden. The alignment would cross under I-90 at approximately a 45-degree angle. The tunnel would end at the bottom of the Keechelus portal shaft, approximately 120 feet below the ground surface.

12.11.2 Tunnel Hydraulic Criteria

Table 11 summarizes the hydraulic criteria for the North Tunnel Alignment. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) discusses tunnel hydraulics analysis and criteria in more detail. Drawings in Appendices A and B show the hydraulic profile.

Table 11. North Tunnel Alignment Hydraulic Design Criteria

Criteria	Design
Hydraulic design	Free flow (nonpressurized) open channel flow tunnel.
Length	21,390 feet
Inside diameter	12-foot boring with 10-foot lined tunnel.
Maximum velocity	10 fps
Slope	- 0.0014
Horizontal curves	Minimum radius of 600 feet (exceeds minimum 20 tunnel diameter radius (TBM drilling method).

12.12 Kachess Lake Road Portal – North Tunnel Alignment

The North Tunnel Alignment from the Keechelus portal shaft would discharge at the Kachess Road portal located adjacent to Kachess Reservoir. This portal would also serve as the primary location of construction activities for boring (using the TBM) or mining of the North Tunnel Alignment tunnel. The Kachess Reservoir end of the tunnel was selected to be the TBM launch and mining portal because it can be an at-grade "drive in" portal. The tunneling operation from there would be a positive (uphill) grade, which allows for gravity flow of drainage from the tunnel. The portal site would also have good access to Kachess Lake Road.

12.12.1 Kachess Road Portal Site

From the northwest side of Kachess Lake Road, the portal site would be excavated into the rock face of the adjacent hillside, far enough to provide approximately a two tunnel diameter cover of rock over the vertical portal face. The rock face would be laid back at a steep angle that is yet to be determined based upon the quality of rock encountered. This excavation would also provide approximately four acres of level area at the road grade adjacent to Kachess Lake Road to site tunnel power and ventilation support systems, as well as for receiving, storing, and loading of tunnel muck onto trucks for hauling via Kachess Lake Road and I-90 to a disposal site.

Once the work area is constructed and the road relocated, the tunnel entrance portal would be constructed using drill and blast methods and supported using rock bolts and shotcrete until a nominal 50-foot-long starter tunnel was constructed to facilitate installing the TBM and trailing gear.

12.12.2 Portal Structures

In addition to the tunnel mining and entrance portal, the following structures would be located at this site:

- Discharge drop structure, which connects the tunnel at invert El. 2,300 to double box culverts at invert El. 2,290.
- An approximately 380-foot-long double box culvert with two 6-foot-square (inside dimensions) sections to convey water from the discharge drop structure under Kachess Lake Road to the lakeshore spillway. The water would exit the box culverts into a transition structure and into a chute spillway.
- A 90-foot-long chute spillway would terminate at a 60-foot-long stilling basin located at the Kachess Reservoir shoreline at El. 2,252, which is 10 feet below the high water elevation of the Kachess Reservoir at El. 2,262.
- Using a baffled apron drop rather than chute spillway and stilling basin would be reevaluated during final design as more complete topographic survey information is available.
- Standard medium voltage power would be connected at the site to supply power for local security lighting, and a level/velocity flow meter in the box culvert.
- Depending upon the lakeshore soil and rock conditions, riprap pad would be sized and placed below the stilling basin discharge to protect the lakebed from erosion when the reservoir was below El. 2,262. The final size, shape, and extent of the riprap area have not yet been determined pending a review of the lakebed materials, slope, and erosion potential. The drawings currently show a 4-foot-thick layer of D50 equal 24-inch riprap pad that is 200 feet long by 30 feet wide for cost estimating purposes.

12.12.3 Kachess Lake Road Temporary Realignment

Based upon preliminary field observations, it appears that Reclamation could temporarily realign approximately 1,100 feet of Kachess Lake Road in the portal area to provide additional room for tunnel mining activities as well as to allow for construction vehicle turnaround and continued vehicular access around the site during construction.

The contractor would cut back the existing rock slope adjacent to the northwest side of the road to approximately El. 2,300. The contractor would use the excavated material to enlarge the work site by filling the area on the south side of the road and as grading material to relocate Kachess Lake Road temporarily.

12.12.4 Kachess Lake Road Portal Electrical Power

Puget Sound Energy electrical power is available along Kachess Lake Road. This electrical power capacity should be adequate to provide typical electrical lighting and construction building service power to the site. The project team anticipates that the construction contractor will use portable generators to provide adequate power for the tunnel boring machine and associated tunneling operations.

12.12.5 Safety

All the structures at this portal would be visible to the public during construction. Contract documents would also describe requirements for traffic control, the temporary Kachess Lake Road detour, and construction signage. Reclamation would screen the site from view after construction, using a berm and tree plantings between the portal and Kachess Lake Road. The berm, rock barriers, chain link fencing, and locked gates would prevent public access into the portal area after construction is completed. Security fencing would also be used to help provide fall prevention on the spillway channel walls.

Permanent access into the portal structure would be via a lockable access hatch and ladder and removable concrete deck panels. Permanent exterior area security lighting and interior drop structure lighting would be included. Reclamation would protect the double box culvert discharge into the spillway by a bar rack with spacing set to prevent public access and discourage animals from entering into the box culvert. The contractor would be responsible for temporary fencing during construction.

12.13 South Tunnel Alignment

12.13.1 South Tunnel

The South Tunnel Alignment is comprised of two tunnel segments, both of which would be mined from the I-90 Exit 62 portal. Table 12 lists lengths of the west tunnel Segment A and the east tunnel Segment B. Based upon these tunnel lengths and 12-foot diameters, approximately 110,000 cy of material would be removed from these two tunnels.

To provide for gravity flow of drainage from each of these tunnels during construction, the contractor would mine the Segment A tunnel upslope from the I-90 Exit 62 portal to the Keechelus portal shaft. The tunnel would end at the bottom of the Keechelus portal shaft approximately 160 feet below the ground surface. The contractor would mine the Segment B tunnel up at a very shallow slope from the I-90 Exit 62 portal to the Kachess Reservoir portal. The tunnel would end at the Kachess Reservoir shoreline at the upper Kachess Reservoir level of El. 2,262.

The contractor would load muck from these two tunnel segments from the portal shaft onto trucks at the site adjacent to the I-90 Exit 62 interchange, thus avoiding truck traffic impacts along Kachess Lake Road associated with the North Tunnel Alignment.

12.13.2 Tunnel Hydraulic Criteria

Table 13 summarizes the hydraulic design criteria for the South Tunnel Alignment. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) discusses tunnel hydraulics analysis and criteria in more detail. Appendices A and B include the hydraulic profile.

Table 12. South Tunnel Alignment Design Criteria

Criteria	Design	
Hydraulic design	Free flow open channel and pressurized flow tunnel.	
Length	Segment A: 9,320 feet	Segment B: 16,770 feet
Inside diameter	12-foot bore with 10-foot lined tunnel	
Maximum velocity	10 fps	10 fps
Slope	Segment A: - 0.0014	Segment B : +0.0001 (positive slope)

12.14 I-90 Exit 62 Portal – South Tunnel Alignment

The I-90 Exit 62 portal serves two purposes for the South Tunnel Alignment:

- A launching shaft for the Segment A tunnel between the Exit 62 portal and the Keechelus portal shaft.
- A launching shaft for the Segment B tunnel between the Exit 62 portal and the Kachess Reservoir portal.

The portal site is 4.5 acres of cleared space adjacent to I-90 Exit 62. The site is within 300 feet of the highway exit. This would provide sufficient room for tunnel mining activities and allow for construction vehicle turnaround and continued vehicular access around the site during construction.

12.14.1 I-90 Exit 62 Portal Site

The project team considered the following factors in the location of this portal:

- It is an existing disturbed and open site used for construction staging and storage.
- There is easy access to I-90 by using the Exit 62 ramps and overpass.
- There is potential to mine both tunnels at the same time.

To accelerate the construction schedule, the tunnel would most likely be constructed using two portal shafts and two TBMs. Therefore the project team assumes that the contractor would excavate the I-90 Exit 62 portal using two 25-foot-diameter shafts with the tunnel work occurring at the bottom of each shaft. To allow for a hydraulic drop from the gravity flow Segment A to a pressurized Segment B, the Segment A shaft would be approximately 93 feet deep. The Segment B shaft would be approximately 160 feet deep. The contractor would mine both tunnel segments with positive grades to allow water seeping into the tunnel during construction to drain back to a sump in the I-90 Exit 62 portal for pumping out of the portal shafts – probably into the adjacent Swamp Lake wetland. If necessary to remove turbidity, the contractor would pump seepage water through holding and treatment tanks prior to discharging the clear water to Swamp Lake.

The contractor would connect the two shafts at the bottom of the Segment A shaft (invert El. 2,317) using an 8-foot-diameter pipe installed in a drill and blast tunnel mined between the two shafts.

The depth to rock at this portal site has not yet been determined. Reclamation is currently planning the next phase of geotechnical borings which would include a boring at this site. Based upon an estimated ground surface El. 2,410, a Segment B tunnel invert at El. 2,260, and plunge pool at El. 2,250 the Segment B portal shaft would be approximately 160 feet deep.

12.14.2 Portal Structures

Since the I-90 Exit 62 portal is an intermediate TBM launching shaft for two tunnels, the contractor has two options for tunneling:

- Use one TBM to mine both Segments A and B by mining the first tunnel, recovering and rebuilding the TBM, and relaunching it to mine the second tunnel.
- Use two TBMs, one for each tunnel segment, allowing concurrent mining of both segments.
- Ventilation for release of air from the portal is required due to the hydraulics in the two connecting tunnels. The open shaft and a ventilation stack through the roof would provide ventilation. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) describes design of the drop shaft and plunge pool in this shaft.

Table 13 lists design criteria for the I-90 Exit 63 portal. The project team based this information on a contractor deciding to drill both tunnels at the same time from this shaft.

Table 13. I-90 Exit 62 Portal Shaft Design Criteria

Criteria	Design
Diameter	Two adjoining 25-foot shafts
Ground surface elevation	2,410
Segment A invert elevation	2,317
Segment B invert elevation	2,260
Plunge pool top of bottom slab elevation	2,250

The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) includes further geotechnical design considerations.

12.14.3 I-90 Exit 62 Portal Electrical Power

Electrical power is available at the I-90 Exit 62 portal site. This electrical power capacity should be adequate to provide typical electrical lighting and construction building service power to the site. The project team anticipates that the contractor will use portable generators to provide adequate power for the tunnel boring machine and associated tunneling operations.

12.14.4 Safety

The contractor would fence the portal structures exposed so the remainder of the site would continue its former purpose as storage and work areas. The large site would provide a more than adequate area for tunnel mucking operations from both shafts. The contractor could use one centrally located crane or two separate cranes to remove the muck from each shaft.

There would be an access hatch and a ladder provided only to an intermediate landing in each shaft. Permanent switchable lighting would be provided for the top part of the portal shaft and landing. The top slabs would have removable concrete access panels to allow for personnel and equipment access into the portal shaft. In accordance with Reclamation Safety and Health Standards, the contractor would likely use a wall rail mounted man-lift system to move personnel from the ground surface to the bottom of the shaft. The contractor may provide temporary scaffolding and ladder or stairway access during construction, and would be responsible for other safety standards during portal construction, such as temporary fencing and fall protection.

12.15 Kachess Reservoir Portal – South Tunnel Alignment

The South Tunnel Alignment Segment B, from the I-90 Exit 62 portal, would discharge at the Kachess Reservoir portal located below Kachess Lake Road between the road and Kachess Reservoir. The Kachess Reservoir portal would be the receiving shaft for the TBM.

The portal site needs to be approximately 2.0 acres of cleared space between Kachess Lake Road and Kachess Reservoir. Since this is a receiving shaft, the site needs to provide an area sized to remove the TBM from the ground, disassemble it, and truck it from the site as well as provide an area for the discharge structure and spillway from the tunnel to Kachess Reservoir.

The selected site is on Federal land within the Okanogan-Wenatchee National Forest (OWNF). The project team selected the site in part to eliminate the need for private property easements.

A gated access road approximately 500 feet long would be required to access the site. After construction, the temporary road would become a permanent gated road to allow for maintenance and inspection of the outlet structures.

The site is on the shoreline of the Kachess Reservoir. The TBM would exit the slope below Kachess Lake Road at invert El. 2,262.5, which is just above the upper water surface elevation of the reservoir. The exit portal site is at an assumed location until more geotechnical information, including the depth to and rock quality, is available. Reclamation may have to relocate the portal during final design once additional geotechnical information becomes available.

The contractor would excavate the shoreline slope below the road to construct a headwall at the TBM exit point. The headwall would consist of a reinforced concrete vertical face with surrounding rock anchored by shotcrete and rock anchors or bolts, as needed, to stabilize the exposed weathered rock face. This would create a block of stabilized rock for the TBM exit site. The tunnel headwall would then also become the upstream face of the tunnel discharge structure.

12.15.1 Kachess Reservoir Portal Site

The project team considered the following factors in the location of this portal:

- Located on Federal property.
- Maximizes the depth of rock cover over the TBM (to be verified by future drilling).
- Ability to place the TBM at the edge of Kachess Reservoir to minimize the length of the outlet structure spillway.

12.15.2 Portal Structures

In addition to the TBM exit point, the following structures would be located at this site:

- Discharge structure at the tunnel headwall then connecting to a concrete or rock-lined channel to the Kachess Reservoir shoreline at El. 2,252.
- Depending upon the lakeshore soil and rock conditions, a riprap channel would be sized and placed below the discharge channel to protect the lakebed from erosion when the reservoir is below El. 2,252. The extent of the riprap area has not yet been determined pending a review of the lakebed materials and the erosion potential. The drawings in Appendix B show a riprapped channel extending into the reservoir to be used for cost estimating purposes.

Table 14 lists portal design criteria.

Table 14. Kachess Reservoir Portal Design Criteria

Criteria	Design
Orientation	Vertical face portal for TBM exit point
Ground surface elevation	Varies sloping bank to reservoir
Tunnel invert elevation	2,262.5

Other design criteria considerations for the Keechelus Reservoir include the following:

- Energy dissipation would be provided by the discharge structure and lined channel. The Hydraulics Technical Memorandum (Reclamation and Ecology, 2014e) describes the design and depth of these structures.
- The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) discusses geotechnical design considerations.

12.15.3 Kachess Reservoir Portal Electrical Power

Puget Sound Energy electrical power is available along Kachess Lake Road that could be extended to the Kachess Reservoir Portal site. There will be minimal power requirements at this portal site. Permanent power would only be needed for lighting and potentially for some flow monitoring systems.

12.15.4 Safety

Safety criteria features would include the use of locked access road gates, enclosed limited access structures, lockable access hatches, and an exit bar rack for the drop structure to discourage animals and prevent people from entering the structures and the tunnel. Operators could remove the rack to provide tunnel access for inspection and maintenance. Fencing would help prevent public access to the spillway channel. Although structures and riprap would generally conform to existing reservoir contours, Reclamation will add buoys and signs to warn boats away from the area. Applicable safety standards from the Reclamation Safety and Health Standards manual would be applied during construction and future operation and maintenance activities. Other safety standards during portal construction, such as temporary security fencing and fall protection, would be the responsibility of the contractor.

13.0 Geotechnical Engineering

The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) summarizes the current findings and preliminary geotechnical criteria for the project in more detail. The discussion below summarizes the geological conditions and geotechnical engineering assumptions used in the feasibility design.

13.1 Yakima River Diversion and Intake

The project team anticipates that surficial deposits in the area of the Yakima River diversion and intake structure consist of river alluvium overlying outwash. The anticipated soil types in the river alluvium down to 30 to 50 feet include poorly graded gravel with silt and sand, cobbles, and boulders, and well graded gravel with sand and cobbles. Below the alluvium, the anticipated soil types in the outwash include poorly graded gravel with silt and well graded sand with silt. Fine-grained lacustrine deposits may occur at greater depths.

The project team anticipates bedrock is present beneath the diversion structure at depths approaching 150 feet.

The project team anticipates that groundwater may be present beneath the diversion structure, at depths as shallow as 24 feet.

For the coarse river alluvium and glacial outwash soils anticipated at the Yakima River diversion and intake, the feasibility design assumed an allowable vertical bearing capacity of 6,400 pounds per square foot (psf). This bearing capacity assumes conventional spread or pad type footings bearing on medium dense to dense, medium to coarse grained sands and gravels at a minimum depth of 4 feet below final grade and below frost susceptibility.

13.2 Yakima River to Keechelus Portal Conveyance

Surficial deposits along the conveyance from the Yakima River diversion and intake structure to the Keechelus portal shaft may include outwash and river alluvium deposits. The anticipated soil types in the outwash include poorly graded gravel with silt and well graded sand with silt. The anticipated soil types in the river alluvium include poorly graded gravel with silt and sand, cobbles, and boulders, and well graded gravel with sand and cobbles. Fine-grained lacustrine deposits may occur at greater depths.

The project team anticipates that bedrock of the Naches Formation may be present along the alignment at depths ranging from 150 feet at the diversion structure to shallow depths near the inlet shaft.

Groundwater along the alignment may be present at depths ranging from 12 to 28 feet.

For the coarse river alluvium and glacial outwash soils anticipated along the pipeline conveyance, the feasibility design assumed loadings similar to those for the Yakima River diversion and intake.

13.3 Keechelus Portal Shaft

The project team anticipates that surficial deposits in the area of the deep inlet shaft consist of river alluvium deposits. The anticipated soil types in the river alluvium include poorly graded gravel with silt and sand, cobbles, and boulders, and well graded gravel with sand and cobbles.

Based upon Reclamation borings in the Keechelus Dam area, the Naches Formation bedrock should be present at relatively shallow depths at the proposed portal shaft site. It is yet to be determined by a boring at the portal site, but it is expected that the depth to bedrock should be on the order of 5 feet to 20 feet.

Groundwater in the area of the Keechelus portal shaft may be present at depths as shallow as 8 feet.

For the coarse river alluvium soils anticipated at the surface of the Keechelus portal shaft, the feasibility design assumed loadings similar to those for the Yakima River diversion and intake.

For the shaft excavation, the project team developed anticipated ground support requirements for the Keechelus portal shaft using the Rock Quality Index or the Q-System developed by Barton et al. The drawings in Appendices A and B show the details of the feasibility level ground support evaluation, and these are assumed to be similar for all the portal excavations.

13.4 North Tunnel Alignment

Reclamation completed five geotechnical borings during the fall of 2013. The borings were located for a straight alignment between the Keechelus portal and the Kachess Road portal. Three of the borings, DH 13-1, 13-2 and 13-5A, are on or near the revised North Tunnel Alignment. All three of these borings found rock of varying types and qualities at proposed tunnel depths. Additional geotechnical information needs to be obtained for the revised North Tunnel Alignment. For purposes of the feasibility design, the project team assumed that the tunnel would be mined by a TBM in rock and that the entire tunnel would be rock bolted and concrete lined.

13.5 South Tunnel Alignment

Reclamation has not undertaken any geotechnical explorations for the South Tunnel Alignment. WSDOT borings in the area associated with I-90 improvements have been limited to shallow borings that were not taken to rock depth.

The South Tunnel Alignment tunnels would be relatively shallow when compared to the North Tunnel Alignment. New geotechnical borings would be required to confirm the depth to rock, but the intent is that both tunnel segments be founded in rock that is underlying the overburden materials.

The South Tunnel Alignment tunnel crosses under I-90 on the same 45-degree crossing angle as the North Tunnel Alignment. After crossing under I-90, the alignment turns southeast to parallel I-90 all the way to the I-90 Exit 62 portal.

For purposes of the feasibility design, the project team assumed that the tunnels would be bored from the I-90 Exit 62 portal using one or more TBMs and that both tunnels would be concrete lined.

13.6 Tunnel Support Systems

The project team developed anticipated ground support requirements for the KKC alternative tunnel alignments using the available data base presented in the KKC Project Geotechnical Interpretation Technical Memorandum and the Rock Quality Index or the Q-System developed by Barton et al. for the design of tunnel supports. The project team anticipates rock support requirements will vary for areas along the alignments where higher in-situ stresses, relative to rock strengths are encountered due to thick overburden or higher stresses associated with the tectonic history at the site. The project team also anticipates rock support requirements will vary for areas along the alignments where high water inflows or pressures are encountered as indicated by the high water flows and high hydrostatic pressures encountered below a depth of 435 feet in drill hole DH-13-3A.

13.6.1 Rock Support Classes

Table 15 shows the four Rock Support Classes developed for the KKC tunnel alignment. The project team has adjusted the Class I support requirements from the suggested Q-System requirements to address structurally controlled instability. The kinematic analysis indicated that No. 8, Grade 60 reinforcing bars have adequate capacity for the anticipated support requirements.

Table 15. Ground Support Requirements – Tunnel Excavation

Rock Support Class	Anticipated Ground Support Requirements
Class I	Spot Bolting, 2.3 meter (7.5 feet) rock bolts
Class II	Systematic Bolting, 2.3 meter (7.5 feet) rock bolts on 1.7 meter (5.5 feet) spacing
Class III	Systematic Bolting, 2.3 meter (7.5 feet) rock bolts on 1.1 meter (3.5 feet) spacing with welded wire mesh
Class IV	Structural Steel Ribs, 1.2 meter (4.0 feet) on center with lagging as needed

As described in Section 6.4.3 of the Geotechnical Interpretation Report, Table 16 provides the assumed percentages of the tunnel alignment for each support class. The percentages for both the North Tunnel Alignment and the South Tunnel Alignment are the same. The basis of the percentages are rock support classes evaluated for conditions of high stress and high water inflows with adjustments to address additional rock support required for weak zones, shear or clay zones, and potential high water inflows.

Table 16. Rock Support Classes – High Stresses and High Water Inflows/Pressures

Rock Support Class	Class I	Class II	Class III	Class IV
Q-Value Range	>1.0	0.4-1.0	0.1-0.4	<0.1
Percent of Total	64	15	11	10

High water inflows could require probing ahead of the TBM to identify wet zones and pregrouting of wet zones ahead of the tunnel excavation to reduce inflows/pressures or possibly by installing drain holes ahead of the tunnel prior to excavation and support. Because there is limited geotechnical information, the high pressure high water inflow and pregrouting were assumed as conditions for the cost estimate.

13.7 I-90 Exit 62 Portal – South Tunnel Alignment

Surficial deposits in the area of I-90 Exit 62 portal likely consist of alpine glacial alluvium deposits. The anticipated soil types include a range of grain sizes from poorly graded gravel with silt to well graded sand with silt. Fine grained lacustrine deposits may be present at greater depths. Bedrock of the Naches Formation may occur at depths ranging from 110 to 150 feet. Groundwater may be present in the area of the shaft at depths as shallow as 25 feet.

13.8 Kachess Road Portal – North Tunnel Alignment

Surficial deposits in the area of the Kachess Road portal structure likely include shallow deposits of recent colluvium. The anticipated soil types in the colluvium include silty sand with gravel and silty sand.

Bedrock of the Naches Formation is likely present beneath the Kachess Road portal structure at depths approaching 30 feet at the east end to near the surface at the west end of the portal structure.

Groundwater beneath the Kachess Road portal structure may occur below the proposed construction.

13.8.1 Double Box Culvert

Surficial deposits in the area of the double box culvert likely include recent colluvium and glacial deposits. The anticipated soil types in the colluvium and glacial deposits include silty sand with gravel and silty sand.

Bedrock of the Naches Formation is likely present beneath the double box culvert at depths ranging from 42 feet, near the center of the culvert, to surface outcrops at the east end.

Groundwater beneath the double box culvert may occur below the proposed construction, but could temporarily perch on the shallow bedrock.

13.8.2 Spillway and Stilling Basin Structure

Surficial deposits along the alignment of the spillway and stilling basin structure at the outlet of the double box culverts likely include recent colluvium and glacial deposits. The anticipated soil types in the colluvium and glacial deposits include silty sand with gravel and silty sand.

Bedrock of the Naches Formation is likely present beneath the chute spillway and energy dissipation structure at depths ranging from surface outcrops at the west end of the structure to depths of 15 to 20 feet at the east end.

Groundwater beneath theses structures is likely to be below the proposed construction.

13.9 Kachess Reservoir Portal – South Tunnel Alignment

Surficial deposits in the area of the Kachess Reservoir for the South Tunnel Alignment likely include shallow deposits of Quaternary alluvium. The anticipated soil types in the alluvium include silty sand with gravel and silty sand.

Bedrock of the Naches Formation likely occurs at depths ranging from 30 to 50 feet below the ground surface in the area of the Kachess Reservoir portal.

Groundwater beneath the Kachess Reservoir portal may be present at shallow depths adjacent to Kachess Reservoir.

13.10 Construction Considerations

13.10.1 Foundations

Foundations should be constructed below frost depth. Any soft or unsuitable foundation soils should be removed and replaced with structural fill.

13.10.2 Construction Dewatering and Unwatering

The glacial outwash and river alluvium present within the area of the pipeline alignment and portals have relatively high hydraulic conductivities likely ranging up to several hundred feet per day or higher. These sediments would yield significant quantities of water during dewatering or other ground water control efforts for project construction.

The project team modeled groundwater conditions to evaluate anticipated dewatering rates required for excavations at the diversion structure, the open cut trench conveyance pipeline, and the jacked tunnel conveyance pipeline. Each scenario was modeled as transient flow and run over a 5-year period to evaluate both initial and long-term dewatering rates. The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) provides more details related to dewatering.

13.10.3 Excavation

Excavation in all soils anticipated in the KKC project should be possible using conventional earth moving equipment. Occasional over size materials, up to 6 feet in maximum dimension, should be anticipated. The project team anticipates that excavation for the conveyance from the Yakima River to the Keechelus portal would be in soils above the rock surface. However, this would depend on the location of the Keechelus portal shaft. Some excavation into the shallow rock surface might be possible with ripping, rock buckets, or a hoe ram, but more significant rock excavation will likely require some blasting. The project team anticipates excavation of the rock tunnel would be performed using the TBM. The contractor would use drill and blast methods for the starter tunnel and the shafts.

In addition to dewatering in excavations, the contractor should divert surface water to prevent it from entering excavations.

13.10.3.1 Soil Cut Slopes

The project team assumed that all cut slopes would be in OSHA Type C soils and require 1.5H-to-1V (horizontal to vertical) cut slopes down to a bench with trench shoring from the bench to the pipeline invert. Trenches and cut slopes greater that 20 feet deep would require design by an engineer based on adequate investigation along the alignment.

13.10.3.2 Rock Cut Slopes

The project team assumed that excavation cut slopes in moderate to highly weathered rock would be 1H-to-1V with minimal support to a depth of 10 feet below the ground surface. For excavation in slightly to moderately weathered rock, at depths greater than 10 feet, rock cut slopes are assumed to be 0.25H-to-1V with rock bolt support; however, these slopes would require design by an engineer based on adequate investigation.

In particular, the Kachess Road portal would require support on all faces with the exception of possibly the south facing cut slope, where no critical wedges were identified that opened into the slope. The project team assumed that the cut slopes would be 1H-to-1V with minimal support in the moderate to highly weathered rock to a depth of 10 feet below the ground surface. From 10 feet to the depth of the excavation, the slopes are assumed to be 0.25H-to-1V with rock bolt support in the slightly to moderately weathered rock.

13.10.3.3 Fill Slopes

The project team assumed that all fill slopes would require 2.0H-to-1V slopes.

13.11 Seismicity

Reclamation recently evaluated seismicity in the project area using a probabilistic seismic hazard analysis for their screening-level engineering analyses (Reclamation, 2014). Reclamation considered four seismic sources, including local active and potentially active faults, background seismicity, megathrust earthquakes on the interface of the Cascadia Subduction Zone, and interslab earthquakes occurring within the subducting slab. The potential seismic loadings at the site are presented in terms of hazard curves, which display ground motion as a function of annual exceedance probability, or the reciprocal of average return period. The hazard curves were developed for typical soil and rock sites. For a typical rock site, the total mean hazard curve for peak horizontal ground acceleration (PHA) indicates PHA values of 0.23 g, 0.53 g, and 0.81 g for return periods of 1,000 years, 10,000 years, and 50,000 years, respectively. For a typical soil site, the total mean hazard curve indicates PHA values of 0.33 g, 0.70 g, and 1.02 g for return periods of 1,000 years, 10,000 years, and 50,000 years, respectively.

14.0 Right-of-Way and Easements

Most of the tunnel alignment and all of the surface features for both project alternatives are located on United States lands and are within the Okanogan-Wenatchee National Forest (OWNF). The Keechelus and Kachess area facilities for both alternatives are located on United States lands under a Reclamation withdrawal within the OWNF. Both alternatives also cross under Washington Department of Transportation (WSDOT) I-90 right-of-way near the Keechelus Reservoir.

The North and South Tunnel Alignments include some sections that cross under undeveloped private property parcels. The North Tunnel Alignment would represent approximately 27.3 acres of these parcels and the South Tunnel Alignment would represent approximately 22.5 acres.

The South Tunnel Alignment includes one section that crosses under an additional undeveloped part of a private parcel just northwest of the I-90, Exit 62 interchange; however, the United States currently holds an existing US right-of-way over this parcel.

15.0 Operation and Maintenance Considerations

15.1 Screen Cleaning System

There are two common types of fish screen cleaning systems: brush cleaning systems and airburst cleaning systems. A brush cleaning system physically cleans the screen using the brush to lift debris off the screen surface. An airburst cleaning system uses high-pressure air to blow debris off the screen.

The most applicable screen cleaning identified for this fish screen is an airburst cleaning system. The physical location within the water channel, the anticipated high sweeping velocities (greater than 0.8 fps), minimal debris from the dam outlet works, and the additional need to control frazil and anchor ice makes the airburst cleaning system more desirable.

Because of the large size of the diversion and the NMFS requirement of an automated fish cleaning system completing a debris removal cycle within a five-minute period, the airburst system would be divided into a four stand alone systems, one for each of the four intake bays.

Each intake bay would have a dedicated 500-gallon air receiver with a 30-horsepower (HP) compressor capable of recharging in no greater than five minutes. The cleaning cycle would be activated first on the upstream most bay and proceed downstream in secession to the fourth bay. The system would release air for approximately two seconds at each bay and the controller would have a 10-second delay before activating the next downstream air cleaning system.

15.2 Sediment and Debris Managment

The project team expects sediment load in the existing channel to be minimal since most sediment settles and is contained within Keechelus Reservoir. Debris in the channel is also expected to be minimal since the channel is relatively short and there are a limited number of trees only on a portion of the south side of the channel. Debris is expected to be limited to leaves and tree branches that may be blown into the channel by the wind.

When the adjustable crest diversion dam is fully retracted, the concrete apron and sloping concrete lip below the fish screens are designed to promote flushing of any accumulated sediment or debris downstream. During low river flow periods, Reclamation could also remove sections of the lower metal deck above the fish screen to provide access for dredging out any sediment that may have accumulated within the fish screen and intake structure.

15.3 Ice Management

To prevent ice from plugging or damaging the screen, Reclamation would need to implement several measures. First, the screen would be thermally isolated using a neoprene strip between the top of the screen and the structural members above the low water level. This would help prevent conduction cooling of the metal screen below the water surface to the air temperature, which may be much colder than the temperature of the water being released from Keechelus Dam. Because channel velocities would be greater than 3 fps and warmer water would be discharged from the bottom of the Keechelus Reservoir outlet works, the design team would not expect frazil ice to form on the screen. Using a small, low pressure air bubbler that releases a small constant air flow across all four intake bays both reduces anchor ice and also assists in keeping floating debris moving across the screens. This small air system would consist of one 15 HP low-pressure air compressor with dedicated two-inch supply lines.

15.4 Flow Control

The design uses a PLC to accept inputs for the desired KKC diversion flow, the Keechelus Dam release rate, and the Yakima River instream flow requirement. The PLC would use those parameters, and real-time water surface elevation and discharge pipeline flow meter data, to adjust the flow diversion dam height and the motorized flow control gate settings. Reclamation would need to test the system during initial operations to refine the PLC algorithm controlling the flow rates at various Keechelus release and KKC diversion rates.

15.5 Safety

Safety considerations include fencing to discourage people and animals people from entering the area; locked hatches and fish screens to keep fish, animals, and people out of the structures and pipeline; and ladders to allow access into and out of enclosed spaces. Railing would be included at the tops of walls, such as around the fish ladder. Additional signage would be added indicated that access to the site is restricted to authorized personnel. Section 22 of the Reclamation Safety and Health Standards for excavation operations lists other safety standards, while Section 23 lists tunnel and shaft construction safety standards. During construction the contractor would be responsible for all safety measures, including when working around the river during construction.

15.6 Operations and Maintenance

Day to day operations would consist of checking on the equipment (SCADA, gates, adjustable crest dam, and fish screen and screen cleaning system), basic maintenance and cleaning, and drive by checks on the portals and outlet structures. Some of these items, such as cleaning the outlet structures, would occur annually.

This facility would need a part time operator. Although Reclamation could set up the control system to control the flow rate using the gates by remote control and can remotely monitor the equipment, the facility contains some equipment such as the fish screens that would need regular maintenance. Reclamation could assign this task to someone working at Keechelus dam. Another task for this operator would include checking on the Kachess portal and discharge structures. The safety and security features of the I-90 Exit 62 portal and Keechelus portal would be checked weekly.

15.7 Replacement

Reclamation will conduct major inspections these facilities on a four-year cycle – alternation between regional and national (TSC) inspection teams. Inspections would look at the condition of the discharge structures, portals, and tunnels. Local operations teams would also conduct annual inspections of each facility.

The project team anticipates a 50-year cycle of replacement for the equipment. This includes the fish screens and their cleaning system, gates, the adjustable crest dam, and the control systems.

15.8 Power

Power is necessary for the air compressors for fish screen cleaning system, gates, adjustable crest dam, control systems and regular building functions like lights and outlets. A propane fueled standby generator would provide power to the diversion area facilities in the event of power failure.

16.0 Construction Considerations and Scheduling

16.1 Keechelus Site Construction Access to I-90

Eastbound construction access would be from the existing gated access from the eastbound lanes of I-90 just east of the Keechelus spillway. Westbound traffic could access the site via I-90 Exit 62 and then proceed to the site via USFS Road NF-54 (Stampede Pass) and NF-5480 to the gated dam access road at the south end of Keechelus Dam. Access from there would either be via the Reclamation roads along the dam crest or behind the dam.

16.2 Keechelus Construction Staging Area and Activities

The staging area below Keechelus Dam would be approximately 2 acres located within in the open area adjacent to the existing Reclamation buildings and RV parking slabs. The following construction activities would be occurring adjacent to the Yakima River diversion, the Keechelus portal, and one of the conveyance routes between the river and the deep portal:

- Truck access for turn around, loading spoils, and unloading materials and equipment.
- Crane for support of shaft excavation and lining construction.
- Stockpile areas for spoils and construction materials.
- Excavators and front end loader for moving materials.
- Tunneling or open cut pipeline construction from the deep shaft to the Yakima River.
- Support equipment for the small TBM tunneling from this portal to the Yakima River intake (Option B).

- Electrical service from temporary overhead power lines connected to the nearby existing overhead power lines.
- Construction office and parking.

16.3 Keechelus Site Safety

Reclamation owns and controls public access to this site during and after construction. Reclamation would need to install security fencing similar to the fencing adjacent to the spillway and channel. Reclamation would also install safety railings on structures, like the top edges of the structural and retaining walls. The contractor would have responsibility for temporary fencing during construction.

Reclamation would need to design the electrical and mechanical systems building to meet electrical safety requirements, including standards for electrical panel separation. The design will need to be suitable for wet conditions. The building would be built with mainly noncombustible materials and would not be used for materials or chemical storage except for lubricants and potentially cleaning materials needed for systems maintenance – although it is more likely that these materials would be stored in the larger, existing Keechelus Dam service building. Reclamation would have fire extinguishers and other required health and safety items in accordance with Reclamation Safety and Health Standards.

16.4 North Alignment Kachess Lake Road Portal Access

The contractor would mine the North Tunnel Alignment from this at-grade portal so all tunnel muck handling and truck loading would occur at this site. The contractor would access the portal site via I-90, Exit 62 and approximately 3.2 miles of Kachess Lake Road. The contractor would temporarily realign approximately 1,100 feet of Kachess Lake Road to provide adequate area for construction activities at the portal and to provide for vehicular access around the site during construction. The contractor would use temporary fencing and lighting to secure the site during construction.

16.5 South Tunnel Alignment I-90 Exit 62 Portal Access

The portal site is next to and accessible from I-90 Exit 62 so security fencing and gated access would be required to limit public access during construction. Reclamation Safety and Health Standards manual would be applied during construction and future operation and maintenance activities. There would be permanent shaft access via a hatch and ladder to an intermediate landing. Access to this landing would allow operators to descend part of the way down the shaft to observe the flow through the portal shaft.

The contractor may provide temporary scaffolding and ladder or stairway access during construction, and would have responsibility for other safety standards during portal construction.

16.6 Care of Water

16.6.1 Keechelus Dam Area

The geotechnical boring information indicates that groundwater would likely be present in any open trench or tunneling excavations. The contractor would dewater the site with deep wells to depress groundwater elevations to below the bottom of the trench excavation and in front of a tunnel boring operation.

As with the existing Keechelus Dam toe drain system, the contractor could likely discharge pumped water that met low turbidity requirements back into the Yakima River downstream of the proposed intake structure. Well development water could be first discharged into the swales within the existing habitat restoration area until the well discharge turbidity is low enough that it could be discharged back into the Yakima River. If necessary, the contractor could initially discharge wells into temporary Baker settling tanks for treatment prior to discharge to either the existing swales or to the Yakima River.

The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) discusses the dewatering design criteria in more detail.

16.6.2 Yakima River Diversion

Reclamation would install the diversion and intake structure in an open cut excavation through glacial outwash and alluvium. Based upon information available from geotechnical borings and site observations, groundwater would likely flow into excavations. Reclamation would site the fish screens and ladder structure along the bank of the Yakima River. Reclamation would install the adjustable crest dam across the river, affecting river flows. Water control would include dewatering wells, cofferdams, and watertight shoring. Sump pumping could also be used to remove seepage and groundwater within excavations. The contractor would install cofferdams and shoring systems around the work area to bypass and maintain river flows during construction.

The work would involve constructing the cofferdam system with one cofferdam across the river upstream of the project and the second cofferdam downstream of the work area. The contractor would use wells adjacent to the excavation and inside the completed cofferdam system to dewater the area inside the cofferdam and shoring system to a depth roughly two to four feet below the bottom of the excavation.

The contractor would convey river flow between the two cofferdams through a steel pipe or pipes. The contractor could construct the cofferdams and bypass system during a period of low volume releases from the Keechelus Dam outlet works. Since construction would likely occur during the summer irrigation season, Reclamation would size the bypass system to convey the full range of Yakima River flows up to 1,200 cfs (currently estimated as a 10-foot-diameter pipe).

As with Option A and B, Reclamation could select alternative locations for disposal of the dewatering system water such as to the existing drainage swales within the habitat restoration area or, if low turbidity limits are met, back into Yakima River downstream of the new diversion and intake facility. If necessary, the contractor could route turbid dewatering water through a basic treatment and sediment removal system prior to discharging to the swales or to the Yakima River.

16.6.3 Keechelus Portal Shaft

The excavation of the upper part of this portal shaft would likely encounter alluvial soil, and the lower part would likely encounter underlying bedrock. Therefore, the portal design would need to address the changing soil conditions from a structural and constructability standpoint. The contractor could excavate the upper section of the portal shaft in the wet inside of an overlapping ring of secant piles that would be extended to bedrock. Therefore, dewatering for shaft construction should not be required. The project team assumed this excavation and shoring method to develop the cost estimate.

The contractor would seal the shaft to minimize entry of groundwater. The contractor could remove small amounts of water with a sump pumping system. At that point, if Reclamation has selected Keechelus local conveyance Option B for construction, the contractor could launch the tunnel from the portal toward the Yakima River intake. After that tunnel is completed, the contractor could continue the portal excavation into the rock, most likely using drill and blast methods, to the bottom of the shaft. The final structure would be lined with concrete.

The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) discusses care of water in more detail.

16.6.4 Kachess Road Portal

Due to limited geotechnical information at this site and for the tunnel, the rates and volumes of water that may be encountered and intercepted by the portal and tunnel excavation are unknown. For the portal excavation, there would be a depth of overburden soil to be removed before encountering rock. The contractor would mine the tunnel up-gradient from this portal, so any water encountered in the tunnel would flow by gravity from the tunnel face back to the Kachess Road portal where it could be routed to a sump and pumped to holding tanks for treatment to within acceptable limits prior to discharge into the Kachess Reservoir.

16.6.5 I-90 Exit 62 Portal Shafts

The excavation of the upper part of this portal shaft would likely encounter alluvial or outwash soil materials, and the lower part could encounter the underlying bedrock. The portal design would address the changing soil conditions from a structural and constructability standpoint. The upper section of the portal shaft could be excavated in the wet within an overlapping ring of secant piles that the contractor would extend and key into bedrock. Therefore dewatering for shaft construction should not be required. The project team assumed this excavation and shoring method for the cost estimate.

The contractor would seal the shaft from most groundwater entering the portal shaft. The contractor could remove small amounts of water with a sump pumping system. At that point, the contractor would launch one or both TBMs and the dewatering and treatment system would be sized to handle the flow rates encountered.

Initial starter tunnel sections in rock for both shafts would require open faced drill and blast methods. It is anticipated that the contractor could manage water from these operations using sumps and sump pumps; but Reclamation would need to review this assumption during final design after more geotechnical information is available from the site.

The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) discusses care of water in more detail.

16.6.6 Kachess Reservoir Portal

The contractor would excavate the TBM exit point into overburden soil to a rock face below Kachess Lake Road. The portal design needs to address the soil and rock conditions encountered. The portal site is to the north of a small seasonal creek; but the project team does not expect that significant dewatering would be required at the site. The contractor would likely construct the end of the discharge channel in late summer or early fall after the reservoir has been drawn down at least 10 feet to below El. 2,252. Therefore, dewatering for structure construction should not be necessary.

16.7 Site Safety

Reclamation owns and controls access to this site so access by the public would be restricted and controlled during and after construction. The trench would be excavated to allow egress by people and animals. The contractor would need to either fence or backfill any deep open trench excavations on a daily basis. The contractor would need to fence portal shafts temporarily during construction. Section 22 of the Reclamation Safety and Health Standards for excavation operations lists other safety standard, while Section 23 lists tunnel and shaft construction safety standards. The contractor would have responsibility for all safety measures including temporary fencing during construction.

16.8 Site Restoration

16.8.1 Keechelus Area

Restoration of the Keechelus Dam construction area, including the intake, pipelines, and portal, would be a combination of understory plants, shrubs, and grass consistent with the neighboring habitat. Reclamation would consult with the USFS in determining species to plant. The contractor would grade the site to drain away from the structures. Reclamation would redesign the existing gravel access roads to allow vehicle access to the new facilities, including consideration of access to a future fish passage facility.

Restoration of the open trench area (Option A) is expected to be a combination of understory plants, shrubs, grass, and native trees consistent with the other habitat in the area. Minimal restoration would be required for the tunnel option (Option B). Restoration would include native and wetland plants that were disturbed by dewatering activities and shaft excavations.

The contractor would regrade the disturbed areas to the original contours. Any existing gravel access roads would be replaced, while any temporary roads (potentially constructed for the dewatering system) would be removed and the area restored.

16.8.2 Kachess Lake Road Area

Restoration of the portal construction would be a combination of understory plants, shrubs, and native trees. The contractor would grade the site to drain away from above-grade structures.

The contractor would regrade the staging area to restore the site to a more natural shape and to obscure the exposed vertical face of the portal visually. Reclamation would leave a gated gravel access road to allow vehicle access to the portal structures. Reclamation would restore Kachess Lake Road to its original alignment with the associated road shoulders, paving, and drainage.

At the portal, the above grade structures would include the concrete or shotcrete with rock bolts face above the tunnel and the exposed components of the tunnel discharge drop structure; the top of structure, removable concrete panels for tunnel entry, and an air ventilation stack. The contractor would regrade the area in front of the portal to provide future portal tunnel access with a built up berm area planted with trees to help screen the portal site from the road.

16.8.3 Kachess Reservoir Portal

Restoration of the portal site would be a combination of understory plants, shrubs, and native trees. The site would be graded to drain away from above grade structures.

At the portal, the above grade structures would include the exposed parts of the tunnel discharge structure, spillway, and stilling basin.

The design does not include electrical service for the Kachess Reservoir portal.

16.9 Construction Sequencing

Table 17 and Table 18 provide examples of potential construction sequencing and scheduling for the construction of the North and South Tunnel Alignment alternatives. These sequences and construction durations represent only one of several ways that a construction contractor could elect to build the facilities for each alternative, so the actual sequences and project durations may vary significantly from these examples. The tables also show sequencing for the Kachess area construction activities, for both the Kachess Road Portal and the Kachess Reservoir Portal.

Appendix D contains a draft, feasibility-level Gantt chart construction schedule showing these activities. Actual construction durations could vary from the assumed durations shown in the tables and the charts.

16.9.1 North Tunnel Alignment

Table 17. Example North Tunnel Alignment Construction Schedule and Sequencing

Quarter	Accumulated Duration (Months)	North Tunnel Alignment Example Construction Sequencing
1	3	Clear the site and realign USFS NF-4900 (extension of Kachess Lake Road). Begin excavating the Kachess Lake Road mining portal; use the excavated material to enlarge the site area. Clear the site for the Keechelus portal, begin shoring the portal shaft, and begin installing the Yakima River Diversion cofferdam and temporary bypass. Order or initiate TBM refurbishing.
2	6	Complete the Kachess Lake Road realignment and prepare the mining portal headwall for initial tunnel excavation. Complete excavating and lining the Keechelus portal shaft to shallow tunnel or pipeline depth. Complete the Yakima River cofferdam and begin excavation and forming for the river diversion, intake portal, and fish screen structure. Relocate the Yakima River gauge to river downstream of the diversion site.
3	9	Begin the Kachess Lake Road starter tunnel. Mobilize the TBM for the KKC tunnel mining. Complete excavation of the Keechelus portal shaft to the depth to begin mining the shallow tunnel to the Yakima River intake. Complete excavation of the Yakima River intake portal to receive the shallow tunnel. Continue construction of the Yakima River diversion and fish screen structure.
4	12	Install the TBM and begin mining of the KKC tunnel from the Kachess Road portal. Begin mining the Keechelus shallow tunnel, or open trench construction. Continue construction of the diversion and fish screen structure.
5	15	Continue TBM mining of the deep tunnel. Continue mining and lining of the shallow tunnel. Continue construction of the Yakima River fish screen and intake structure.
6	18	Continue TBM mining of the deep tunnel. Complete mining and lining of the shallow tunnel; restart excavation and lining of the Keechelus portal shaft to the deep tunnel. Complete construction of the fish screen and intake structure.
7	21	Continue TBM mining of the deep tunnel. Continue excavation and lining of the Keechelus portal shaft to deep tunnel depth. Complete construction of the fish screen controls and mechanical systems.
8	24	Continue TBM mining of the deep tunnel. Complete construction of the Keechelus portal shaft to tunnel depth. Begin construction of the de-aeration chamber and deep tunnel receiving section.
9	27	Begin construction of the Kachess Lake Road discharge structure and conveyance. Continue TBM mining of the deep tunnel. Complete construction of the de-aeration chamber and plunge pool; begin construction of remaining deep tunnel portal structure.
10	30	Continue TBM mining of the deep tunnel. Begin construction of the Kachess Lake Road tunnel discharge drop structure, and box culvert to spillway. Depending upon reservoir elevation, place Kachess Reservoir riprap. Begin construction of the Keechelus portal shaft lid and installation of remaining mechanical, electrical, and control systems at the portal and Yakima River intake.

Quarter	Accumulated Duration (Months)	North Tunnel Alignment Example Construction Sequencing
11	33	Complete TBM mining of the deep tunnel and removal of the TBM. Begin tunnel lining. Relocate and open Kachess Lake Road. Construct remaining portions of Kachess discharge transition and spillway. Begin site restoration and cleanup. Complete placing Kachess Reservoir riprap. Complete construction of the Keechelus portal shaft and installation of remaining mechanical, electrical, and control systems at the portal and Yakima River intake.
12	36	Continue tunnel lining. Complete Keechelus site work and restoration.
13	39	Complete tunnel lining. Remove and restore temporary road alignment and site. Final conveyance system inspection. Restore roads used for access. Startup and testing. Restore Kachess Lake Road as needed and required.
14	42	Complete final testing and acceptance, and place tunnel in operation.

16.9.2 Kachess Road Portal Construction Sequencing

The construction sequencing at the Kachess Road portal would be as follows:

1. Clear a route and prepare a road grade for relocating about 1,100 feet of Kachess Lake Road.
2. Close the existing road and reroute traffic to a temporary detour.
3. Begin excavation into the hillside to create the vertical face for the tunnel-mining portal. Use the excavated materials to create a relatively level work area in front of the portal.
4. Haul out excess excavated material.
5. Stabilize the hillside around the portal with benching or shotcrete, or both.
6. Construct the portal face and drill and blast mine the first approximately 50 feet of tunnel into the rock face of the portal.
7. Mobilize and launch the tunneling TBM toward the Keechelus portal.
8. Load tunnel muck onto trucks for hauling away on Kachess Lake Road to I-90 and then on to a disposal site that is yet to be determined.
9. Store and provide tunnel-lining materials as the tunnel advances.
10. Once tunnel mining and lining have been completed, excavate in front of the portal for the discharge drop structure.
11. Construct the discharge drop structure.
12. Excavate and construct the first section of the double-box culvert to beyond the permanent Kachess Lake Road alignment.

13. Regrade and restore the portal area, including a screening berm and plantings between the road and the portal.
14. Restore Kachess Lake Road to its original alignment and open to traffic.
15. Use the temporary road for access to excavate and construct the remaining section of the double box culvert, spillway transition, spillway, and stilling basin.
16. If needed, and depending upon Kachess Reservoir elevations, install riprap on the lake bottom below the spillway stilling basin.
17. Remove the temporary road and restore the temporary road alignment to natural conditions.

16.9.3 South Tunnel Alignment

Table 18. Example South Tunnel Alignment Construction Schedule and Sequencing

Quarter	Accumulated Duration (Months)	South Tunnel Alignment Example Construction Sequencing
1	3	Clear the I-90 site. Begin secant pile shoring of the I-90 mining portal shafts. Clear the site for the Keechelus Dam receiving portal and begin installing a Yakima River Diversion cofferdam and temporary bypass. Order TBMs.
2	6	Begin excavating of the I-90 portal shafts. Begin and complete secant pile shoring of the Keechelus portal shafts. Complete the Yakima River cofferdam and begin excavation for the river diversion, intake portal, and fish screen structure.
3	9	Complete excavation of the I-90 Segment A and Segment B portals to tunnel depths. Complete excavation of the Keechelus portal shaft to the depth to begin mining the shallow tunnel (if Option B is selected) to the Yakima River intake. Complete excavation of the Yakima River intake portal to receive the shallow tunnel. Begin construction of the Yakima River diversion and fish screen structure.
4	12	Begin and complete mining of the starter tunnels from the I-90 portals for both tunnel Segments A and B. Continue mining the Keechelus shallow tunnel; continue construction of the diversion and fish screen structure.
5	15	Mobilize and install the TBM for tunnel Segments A and B. Begin TBM mining of Segments A and B. Complete mining of the shallow tunnel for Option B (or open cut pipeline for Option A). Complete construction of the diversion and continue construction of the Yakima River fish screen and intake structure.
6	18	Continue TBM mining of tunnel Segments A and B. Begin rock excavation of the Keechelus portal shaft to Segment A depth. Complete construction of the fish screen and intake structure.
7	21	Continue TBM mining of tunnel Segments A and B. Complete excavation of the Keechelus receiving portal shaft to Segment A depth. Complete construction of the fish screen and support facilities for the intake structure.

Quarter	Accumulated Duration (Months)	South Tunnel Alignment Example Construction Sequencing
8	24	Complete TBM mining Segment A and remove TBM. Begin Segment A lining. Continue mining Segment B. Begin construction of the Kachess Reservoir cofferdam and discharge structure. Complete construction of the deep tunnel shaft lining. Begin construction of the de-aeration chamber and deep tunnel receiving section.
9	27	Continue Segment A lining, continue TBM mining of Segment B.; Complete construction of the de-aeration chamber, and excavate Keechelus plunge pool. Complete the first stage of construction of the Kachess Reservoir discharge structure.
10	30	Complete Segment A lining. Complete Segment B tunnel mining and dismantle and remove the TBMs from the Kachess portal. Begin Segment B lining. Begin Keechelus portal and plunge pool concrete lining.
11	33	Continue Segment B lining. Complete Keechelus portal and plunge pool concrete lining.
12	36	Continue Segment B lining. Complete construction of the I-90 portals connection, hydraulic control structure, plunge pool, and shaft portal lids. Begin and complete construction of the second stage of the Kachess Reservoir tunnel discharge structure. Complete remaining Keechelus portal structure (lid and control features) and the installation of remaining mechanical, electrical, and control systems at the portals and Yakima River intake.
13	39	Complete Segment B lining. Complete construction of the Kachess Reservoir tunnel discharge structure. Depending upon reservoir elevation, place Kachess Reservoir riprap. Begin and complete Keechelus, I-90, Kachess disturbed areas site work and site restoration.
14	42	Complete final testing and acceptance, and place tunnel in operation.

16.9.4 Kachess Reservoir Portal Construction Sequencing

Construction access to the site would be via I-90, Exit 62 and Kachess Lake Road.

The construction sequencing at the Kachess Reservoir portal would be as follows:

1. Clear a route and prepare an access road to the South Tunnel discharge site.
2. Clear and grub the site.
3. Excavate and level the site for the headwall and discharge structure.
4. Haul out the excess excavated material.
5. Construct the headwall, and rock anchor and shotcrete the bank to stabilize the tunnel exit point.
6. Construct the discharge structure and spillway bottom and sidewalls.
7. As reservoir elevations permit, construct the stilling basin slab and walls and install riprap (if needed) into the reservoir.
8. Receive and disassemble the TBM and remove from the site.
9. Construct the discharge structure top slab, interior walls, and bar rack.
10. Restore the site and finish the road as a permanent gated access road to the site.

17.0 Field Cost Estimates

HDR developed a detailed field cost estimate for each of the alternatives and options. The Field Cost Estimate Technical Memorandum (Reclamation and Ecology, 2014c) provides detailed cost information for each project element and explanations of cost estimating methodology.

Table 19 to Table 22 summarize the subtotal construction costs, without markup percentages, used to calculate the field cost estimates for each of the combination of alternatives:

- North Tunnel Alignment – Option A.
- North Tunnel Alignment – Option B.
- South Tunnel Alignment – Option A.
- South Tunnel Alignment – Option B.

The subtotals include labor, materials, equipment, and subcontractors.

Table 19. Subtotal for North Tunnel Alignment - Option A

Item	Cost
Yakima River Diversion & Intake Yakima River Diversion & Intake	$7,979,000
Conveyance from Intake to Keechelus Portal - Option A	$5,759,000
Keechelus Portal - Option A	$2,832,000
North Tunnel	$89,790,000
Kachess Lake Road Portal	$6,755,000
Subtotal	$113,120,000

Table 20. Subtotal for North Tunnel Alignment - Option B

Item	Cost
Yakima River Diversion & Intake	$7,979,000
Conveyance from Intake to Keechelus Portal - Option B	$5,565,000
Keechelus Portal - Option B	$2,996,000
North Tunnel	$89,790,000
Kachess Lake Road Portal	$6,755,000
Subtotal	$113,090,000

Table 21. Subtotal for South Tunnel Alignment - Option A

Item	Cost
Yakima River Diversion & Intake	$7,979,000
Conveyance from Intake to Keechelus Portal - Option A	$5,759,000
Keechelus Portal - Option A	$2,832,000
South Tunnel	$102,343,000
I-90 Exit 62 Portal	$7,077,000
Kachess Reservoir Portal	$4,369,000
Subtotal	$130,360,000

Table 22. Subtotal for South Tunnel Alignment - Option B

Item	Cost
Yakima River Diversion & Intake	$7,979,000
Conveyance from Intake to Keechelus Portal - Option B	$5,565,000
Keechelus Portal - Option B	$2,996,000
South Tunnel	$102,343,000
I-90 Exit 62 Portal	$7,077,000
Kachess Reservoir Portal	$4,369,000
Subtotal	$130,330,000

Table 23 summarizes the total field cost estimates developed for the four KKC project alternatives. Estimated costs are in 2014 dollars (second quarter).

Table 23. Field Costs for KKC Alternatives

Item	%	North Tunnel Alignment		South Tunnel Alignment	
		Option A	Option B	Option A	Option B
Materials & Labor Cost[1]	-	$ 113,120,000	$ 113,090,000	$ 130,360,000	$ 130,330,000
Contractor's Field Overhead	8.0%	$ 9,050,000	$ 9,048,000	$ 10,429,000	$ 10,427,000
Mobilization	5.0%	$ 5,656,000	$ 5,655,000	$ 6,518,000	$ 6,517,000
Unlisted Items Minor	4.0%	$ 4,525,000	$ 4,524,000	$ 5,215,000	$ 5,214,000
Design and Scope Changes Minor	4.0%	$ 4,525,000	$ 4,524,000	$ 5,215,000	$ 5,214,000
Cost Estimate Refinements Minor	2.0%	$ 2,263,000	$ 2,262,000	$ 2,608,000	$ 2,607,000
Contractor's Fee	15%	$ 20,871,000	$ 20,866,000	$ 24,052,000	$ 24,047,000
Contractor's Bond & Insurance	2%	$ 2,401,000	$ 2,400,000	$ 2,766,000	$ 2,766,000
Sales Tax (Materials & Equipment)	8.2%	$ 1,908,000	$ 1,874,000	$ 2,049,000	$ 2,016,000
Contract Cost	-	$ 164,319,000	$ 164,243,000	$ 189,212,000	$ 189,138,000
Contingency	25%	$ 41,080,000	$ 41,061,000	$ 47,303,000	$ 47,285,000
Subtotal	-	$ 205,399,000	$ 205,304,000	$ 236,515,000	$ 236,423,000
Escalation to Midpoint of Construction (11/30/2016)	5.4%	$ 11,092,000	$ 11,087,000	$ 12,772,000	$ 12,767,000
Gross Receipts Tax	0.484%	$ 1,048,000	$ 1,048,000	$ 1,207,000	$ 1,207,000
Field Cost (Low End)[2]	-20%	$ 174,100,000	$ 174,000,000	$ 200,400,000	$ 200,400,000
Field Cost[2]	-	$ 217,600,000	$ 217,500,000	$ 250,500,000	$ 250,400,000
Field Cost (High End)[2]	40%	$ 304,700,000	$ 304,500,000	$ 350,700,000	$ 350,600,000

1. Subtotal includes labor, materials, equipment, and subcontractors.
2. Values have been rounded up to the nearest $100,000.

18.0 Information Needs

This section lists additional information necessary for continuing the next phase of design.

18.1 Surveying

The following list identifies surveying needs:

- Aerial LiDAR survey data of the selected tunnel alignment corridor was collected in 2014. As of late 2014, Reclamation was reducing the LiDAR data and producing new maps.
- Consolidation of survey information that Reclamation has assembled for the Keechelus Dam area. There is a datum discrepancy between the two survey files provided by Reclamation.
- Additional, as required, ground survey of the Keechelus Dam and Kachess Reservoir project facilities sites to pick up tree-obscured areas, details, and locates not covered by the aerial survey.

18.2 Geotechnical

Geological borings, monitoring wells, and a testing program are necessary to support the tunnel design effort and the dewatering system for the KKC project. Reclamation would use the information gathered to model the groundwater conditions in this complex area. The Geotechnical Interpretation Technical Memorandum (Reclamation and Ecology, 2014d) provides detailed recommendations for field investigations. Reclamation would also use the geological borings to look for the presence of cobbles, boulders, and hard rock layers, and to determine other tunneling and structural design parameters. Reclamation would use the data for the eventual development of a Geotechnical Baseline Report.

18.2.1 Keechelus Dam Area

The project team has identified the following geotechnical needs in the Keechelus Dam area:

- Depth to rock, presence of boulders and parameters for pipe jacking; and dewatering are the greatest uncertainties and data gaps along the conveyance Options A and B and require additional investigation.
- Pump tests in the Keechelus diversion and conveyance routes area are needed to better determine the range of expected dewatering system flow rates, well sizes, and well spacing for the dewatering wells that would be required to construct either. Pump test information would be provided to the contractor to plan both initial and long-term dewatering rates for the dewatering effort.
- The hydrogeologic data currently available for the dewatering design is limited to a few shallow borings and test pits within the pipeline alignment and portal shafts and one deep boring north of the project area. No aquifer hydraulic parameters are available within the project area.
- The depth to a suitable cut off layer for dewatering, the lacustrine deposits, is a data gap and requires additional investigation. Geophysics survey and analysis of the project area below Keechelus Dam to help determine the depth to rock in the area. Additional geotechnical borings and monitoring wells at the Keechelus portal sites and along the Option A and Option B conveyance alignments.
- A cofferdam structure for the diversion and care of the Yakima River during construction of the diversion and intake is also an uncertainty. The foundation conditions related to the construction and performance of the cofferdam is a data gap and requires additional investigation.

18.2.2 North and South Tunnel Alignments

There is a large data gap related to subsurface information, including geo-mechanical and hydrogeological, along most of the tunnel alignments. The project team has identified the following geotechnical needs for both tunnel alignments:

- Additional geotechnical borings and testing are needed to look at rock strength and in-situ stresses in the rock mass. Complete and accurate rock mass characterization is the greatest uncertainty for both alternate tunnel alignments, in particular in areas of the tunnel with high overburden.

- The hydrogeology and groundwater conditions along the tunnel alignments are also major risk and uncertainties.

Information on rock parameters would inform the use of tunneling equipment, amount of rock bolting and other support methods necessary, and determine the parameters for tunnel lining and to support shaft and tunnel design for either alternative.

18.2.3 Kachess Reservoir Areas

Depth to rock and accurate rock mass characterization are the greatest uncertainties and data gaps for the Kachess Road portal and require additional investigation.

18.2.4 Continuing Data Collection

The project team installed instrumentation in some of the 2013 borings. Reclamation needs to collect data from existing piezometers, where possible, on a regular basis and in sufficient quantities to be valuable for continuing design efforts. Any new exploration boreholes should also include a vibrating wire piezometer.

Reclamation has completed two additional geotechnical exploration boreholes, and will be testing, and reporting on those findings during the winter of 15. They will resume drilling additional boreholes in the spring of 2015. Reclamation will use the findings of these additional explorations, testing, and reporting to verify the assumptions used for the feasibility design and cost estimates. An addendum to this report will then be prepared to refine the design and update cost estimates, as appropriate for the selected alternative.

19.0 Comparison of Alternatives

Table 24 presents a summary comparison table of the project characteristics and a discussion of relative advantages and disadvantages of the project alternatives.

Table 24. Comparison Summary of KKC Alternatives

Characteristic	North Tunnel Alignment	South Tunnel Alignment	Advantages/Disadvantages
Diversion and Intake	Yakima River diversion and intake		The Yakima River diversion and intake is the same for both alternatives.
Conveyance from Yakima River Intake to Keechelus Portal	Option A (1,440-foot pipeline) Option B (1,200-foot tunnel)		Options A and B are the same for both alternatives. Option A (pipeline) appears to be the lowest construction cost and would most likely involve less construction risk than Option B (tunnel).
Keechelus Portal	130’ deep, 25’ diameter shaft		The same for both alternatives.
Deep Tunnel Length	21,390-foot-long	9,310’ (Seg A) 16,770’ (Seg B)	The South Tunnel is approximately 4,700-feet longer than the North Tunnel.
Intermediate Portal	None	Adjacent 25-foot-diameter shafts near I-90 Exit 62	The South Tunnel requires intermediate I-90 Exit 62 portals which could allow concurrent tunnel mining in two directions. Intermediate portals may also provide an advantage for tunnel ventilation.
Deep Tunnel Excavation	From at grade Kachess Road portal	From I-90 Exit 62 deep portal shafts	Kachess Road portal provides the advantage of an at-grade access to the tunnel and for muck removal. The I-90 Exit 62 portal could provide the advantage of concurrent mining in two directions, but would require muck removal from deep shafts.
Tunnel Unwatering During Construction	Drain by gravity to the Kachess Lake Rd Portal	Require pumping from the I-90 Exit 62 Portal shafts	The North Tunnel would drain by gravity to the at grade Kachess Lake Rd Portal. The South tunnel would drain by gravity to the Exit 62 portal, but would then require pumping from the deep shafts to the surface.
Deep Tunnel Muck Disposal	Haul via Kachess Lake Road to I-90	Adjacent to and direct access to I-90 Exit 62	The North Tunnel would have the disadvantage of adding significant truck traffic to Kachess Lake Road. The South Tunnel has the advantage of limiting muck hauling disposal activities to the area near I-90 Exit 62.
Primary Construction Activities Local Impacts	Keechelus Dam area and the Kachess Road portal	Keechelus Dam area and the I-90 Exit 62 portal	The South Tunnel advantage by locating most tunnel mining construction activities in an already disturbed area next to I-90 Exit 62. North Tunnel construction activities around the Kachess Lake Rd portal would require temporary relocation of Kachess Lake Road during construction and result in some disruption of local traffic to the Kachess Reservoir campground.
Hydraulics	Uniform gravity free flow	Gravity and pressure flow	The North Tunnel provides the advantage of a uniform gravity free flow for its entire length. The South Tunnel would be a combination of gravity free flow (Segment A) and pressurized flow (Segment B) hydraulics with an intermediate drop shaft.
Kachess Discharge Structure	Drop structure, box culvert and spillway	Cut and cover pipeline to dis-charge structure	The North Tunnel discharge system is more complex and visible than the South Tunnel discharge structure.
Geotechnical	Deeper tunnel alignment	Shallower tunnel alignment	There is limited geotechnical data available for both alternatives. More data will be required to determine any specific advantages or disadvantages for either alignment.
Estimated Field Costs ($million)	$127 to $227	$148 to $263	Based upon currently available information, the North Tunnel is approximately between $21 million and $36 million (15%) less in field cost than the South Tunnel.
Operations and Maintenance	Most operational activities will be at the Yakima River diversion and intake		Although the South Tunnel has more complex tunnel hydraulics, most of the system operations and maintenance for both alternatives will occur at the Yakima River diversion and intake.

20.0 References

Reclamation, 1994a	Bureau of Reclamation (U.S. Department of the Interior). 1994. *Design Standards No. 3, Water Conveyance Systems, Chapter 4 Tunnels, Shafts, and Caverns.* Prepared by U.S. Department of the Interior Bureau of Reclamation Technical Service Center, Denver, CO.
Reclamation, 1994b	Bureau of Reclamation (U.S. Department of the Interior). 1994. *Design Standards No. 3, Water Conveyance Systems, Chapter 11 General Hydraulic Considerations.* Prepared by Reclamation Technical Service Center, Denver, CO.
Reclamation and Ecology, 2011a	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2011. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus-to-Kachess Pipeline.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2011b	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2011. *Yakima River Basin Study, Volume 1, Proposed Integrated Water Resource Management Plan*. Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2012	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2012. *Yakima River Basin Integrated Water Resource Management Plan, Final Programmatic Environmental Impact Statement.* Prepared by HDR Engineering, Inc., et al. Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2013	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2013. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Screening of Alternatives for the Keechelus-to-Kachess Conveyance Project.* Prepared by HDR Engineering, Inc. and Anchor QEA, Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation, 2014	Bureau of Reclamation (U.S. Department of the Interior). 2014. *Yakima River Basin Integrated Water Resource Management Plan, Value Analysis Keechelus-to-Kachess Conveyance Project.* Prepared by Reclamation.
Reclamation and Ecology, 2014a	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Hydrologic Modeling of System Improvements, Phase 1 Report.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. R13PC10006 ID/IQ.
Reclamation and Ecology, 2014b	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus-to-Kachess Design Criteria.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.

Reclamation and Ecology, 2014c	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus-to-Kachess Field Cost Estimate.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2014d	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus-to-Kachess Conveyance Geotechnical Interpretation.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2014e	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus-to-Kachess Conveyance Hydraulics.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. 08CA10677A ID/IQ.
Reclamation and Ecology, 2014f	Bureau of Reclamation (U.S. Department of the Interior) and Washington State Department of Ecology. 2014. *Yakima River Basin Integrated Water Resource Management Plan, Technical Memorandum: Keechelus and Kachess Dams Fish Passage Concepts Review.* Prepared by HDR Engineering, Inc., Reclamation, Contract No. R13PC10006 ID/IQ.
National Marine Fisheries Service, 2011	National Marine Fisheries Service, Northwest Region (U.S. Department of Commerce). 2011. Anadromous Salmonid Passage Facility Design.
Shannon & Wilson 2014	Shannon & Wilson, Inc. 2014. Geotechnical Data Report, Keechelus to Kachess Conveyance Project (KKC), Kittitas County, Washington.

21.0 List of Preparers

NAME	BACKGROUND	RESPONSIBILITY
HDR, Inc.		
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Colleen Petilla	Engineering	Project Engineer
Troy Gibbs	Engineering	Project Engineer
Sri Rajah	Engineering	Hydraulics
John Ballegeer	Engineering	Geotechnical
John Charlton	Geology	Geology
John Koreny	Hydrogeology	Dewatering
John Nelson	Engineering	Fish Screening and Passage
George (Herb) Hickman	Cost Estimating	Cost Estimator
Richard Glasson	Cost Estimating	Cost Estimate Quality Control Review
Mark Ohlstrom	Engineering	Quality Control Review
Brierley Associates		
Gregg Sherry	Engineering	Tunneling Quality Control Review
Dr. Mole, Inc.		
Gary Brierley	Engineering	Geotechnical Quality Control Review
Engineering Solutions, LLC		
Dan Hertel	Engineering	Civil Constructability Quality Control Review
Reclamation		
Jeremy Lorberau	Engineering	Review

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Appendix A
North Tunnel Alignment Drawings

1G-001	Cover Sheet – Location Maps and Sheet Index
1C-101	Gravity Tunnel Site Plan and Profile
1C-102	Gravity Tunnel Hydraulic Profile
1C-103	Gravity Tunnel Typical Sections
1C-201	Keechelus Diversion Area Site Plan
1C-202	Yakima River Diversion & Intake Site Plan
1C-203	Yakima River Diversion Dam Plan and Sections
1C-204	Yakima River Fish Screen Plan
1C-205	Yakima River Intake Details
1C-206	Yakima River Intake to Keechelus Portal Profiles
1C-301	Keechelus Portal Site Plan and Section
1C-302	Keechelus Portal Sections and Details
1C-401	Kachess Road Portal and Temporary Road Site Plan
1C-402	Kachess Road Portal & Discharge Structure Plan and Profile
1C-403	Kachess Road Portal & Box Culvert Plan and Profile
1C-404	Kachess Road Portal & Spillway/Stilling Basin Plan and Profile
1C-405	Kachess Road Portal & Spillway/Stilling Basin Details

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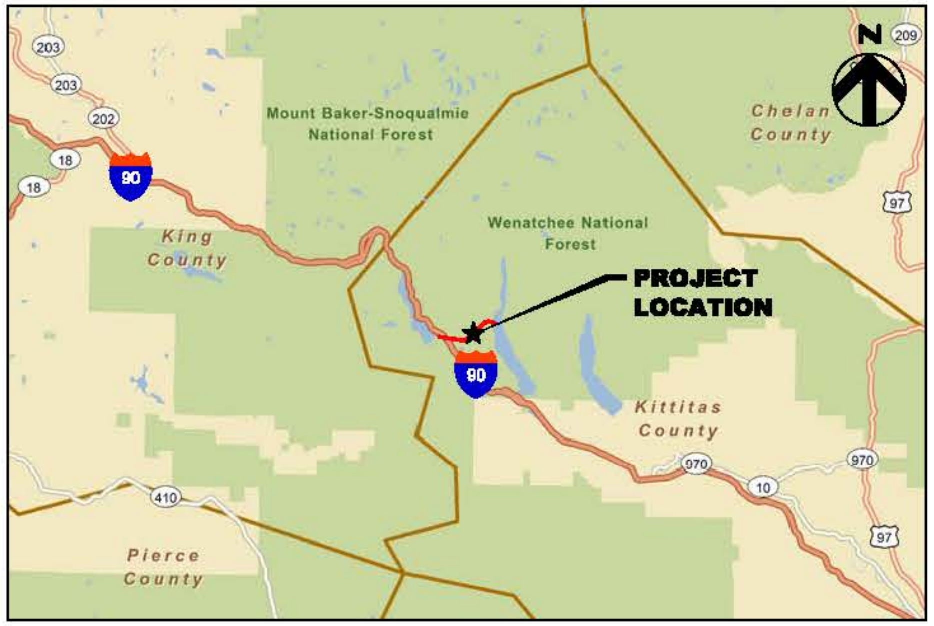

VICINITY MAP
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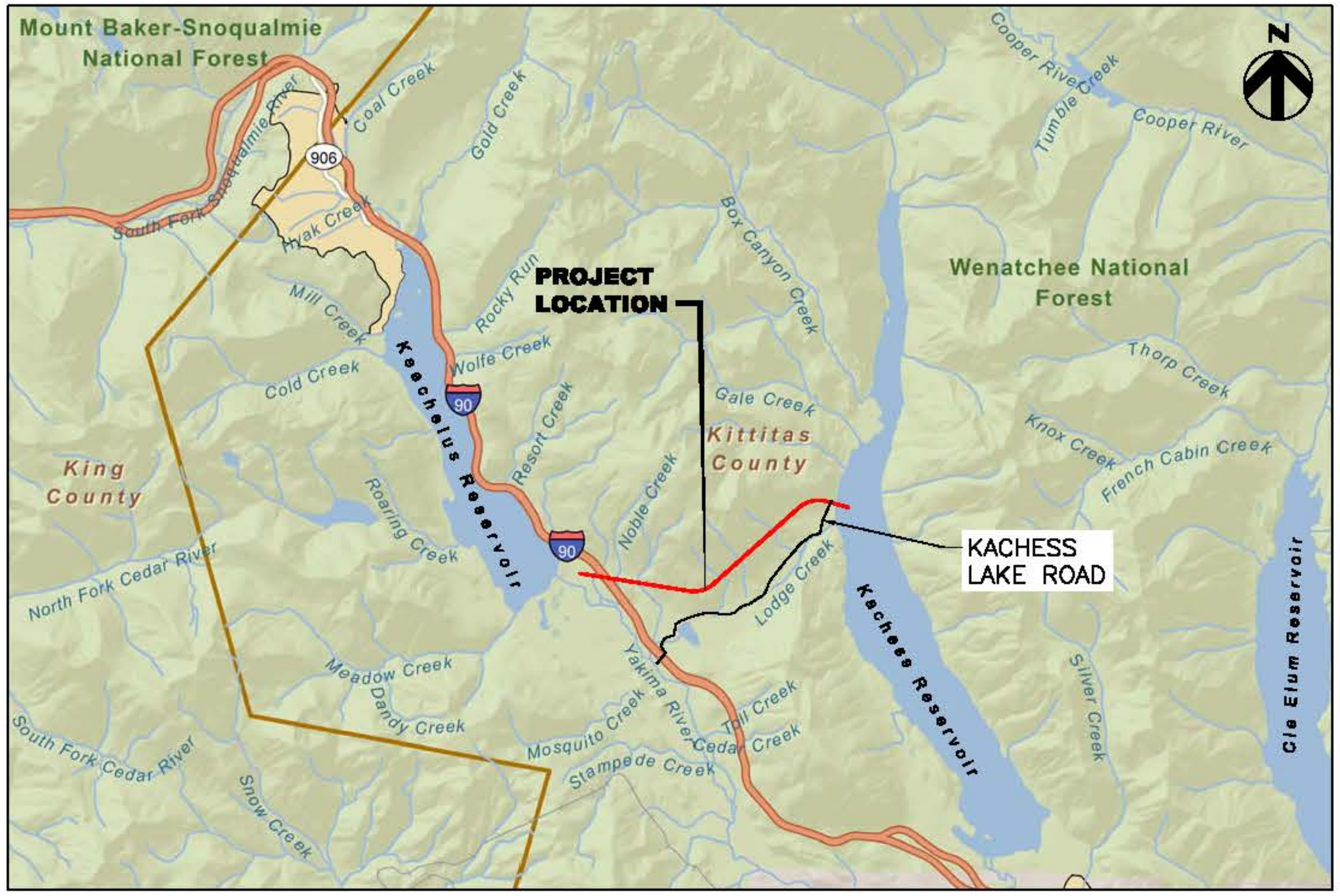
INDEX OF DRAWINGS



LOCATION MAP
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Feasibility Design Drawings For

Bureau of Reclamation

Yakima River Basin Integrated Water Resources Management Plan

Keechelus-to-Kachess Conveyance

North Tunnel Alignment

HDR Project No: 224009

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

RECLAMATION
Managing Water in the West

HDR

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

S. RAJAH
DESIGNED

J. PETERSON
REVIEWED

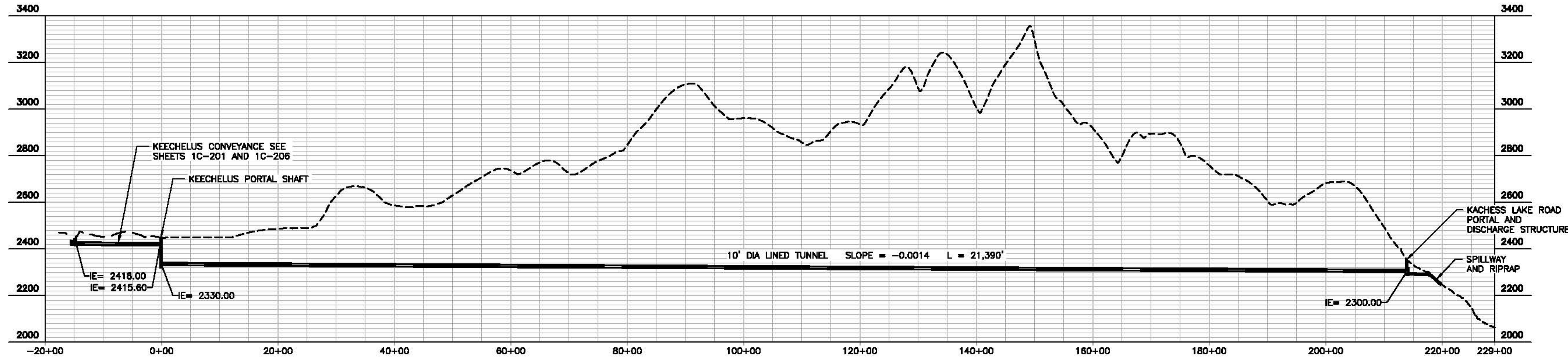
YAKIMA, WA 2014-08-20

COVER SHEET – LOCATION MAPS AND SHEET INDEX

NORTH TUNNEL ALIGNMENT

1G-001

SHEET 1 OF 17



PROFILE

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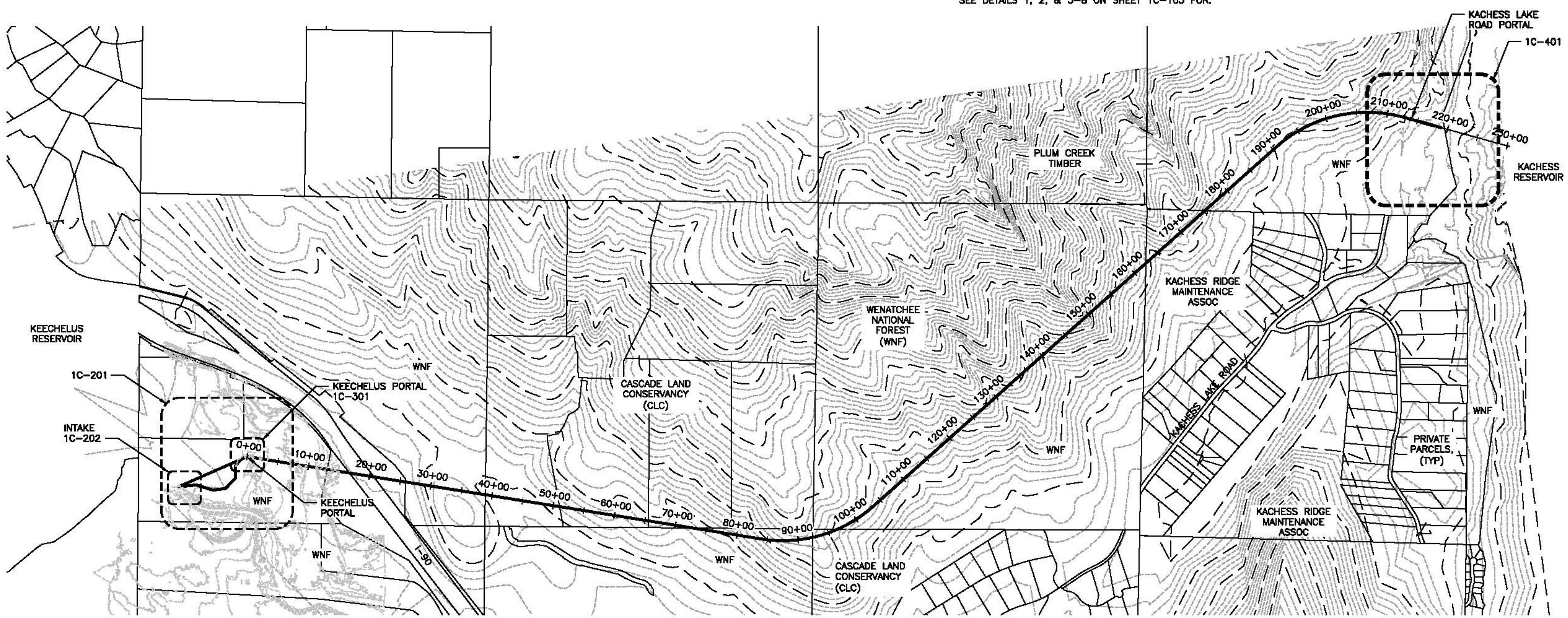
NOTE:
TUNNEL SECTIONS VARY BASED ON ROCK CONDITIONS.
SEE DETAILS 1, 2, & 5-8 ON SHEET 1C-103 FOR.



OVERALL SITE PLAN

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SCALE IN FEET

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FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

RECLAMATION
Managing Water in the West

HDR

JAMES C. PETERSON — STATE OF WASHINGTON — 27574 — REGISTERED PROFESSIONAL ENGINEER

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YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. PETERSON
REVIEWED S. RAJAH
YAKIMA, WA 2014-08-20

GRAVITY TUNNEL SITE PLAN AND PROFILE

NORTH TUNNEL ALIGNMENT

1C-101

SHEET 2 OF 17

DATE AND TIME PLOTTED Not Plotted
PLOTTED BY Not Plotted
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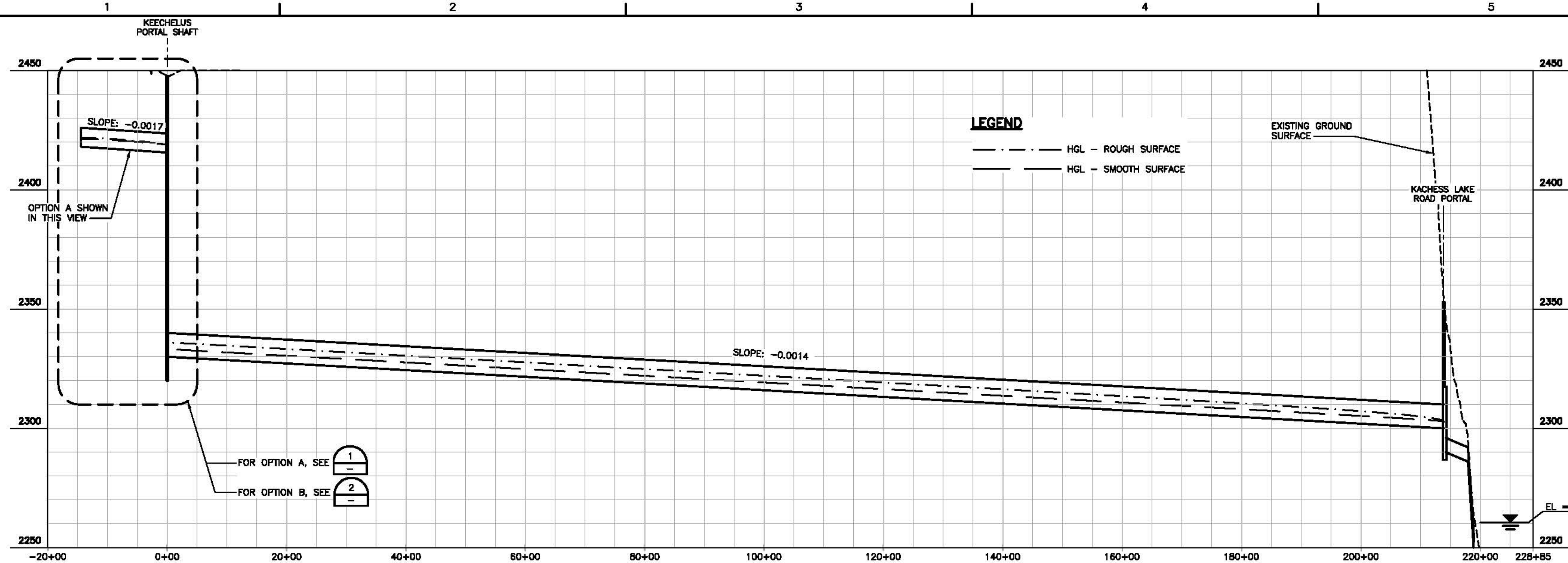
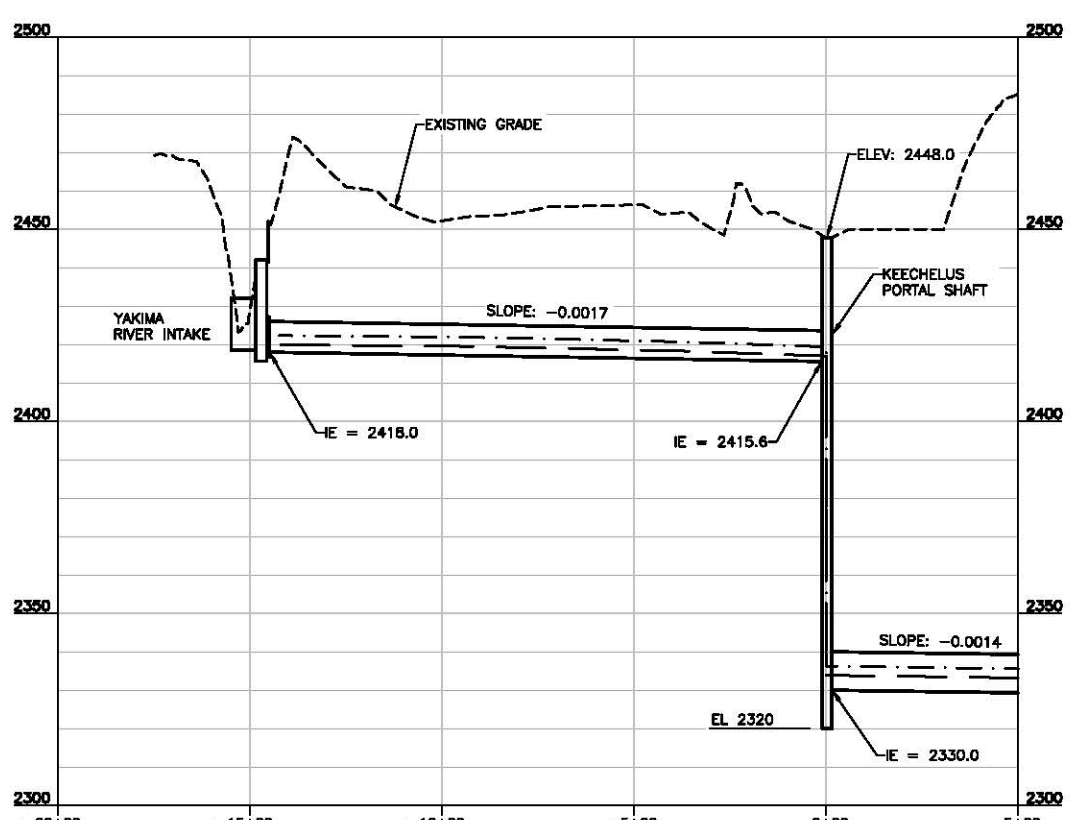


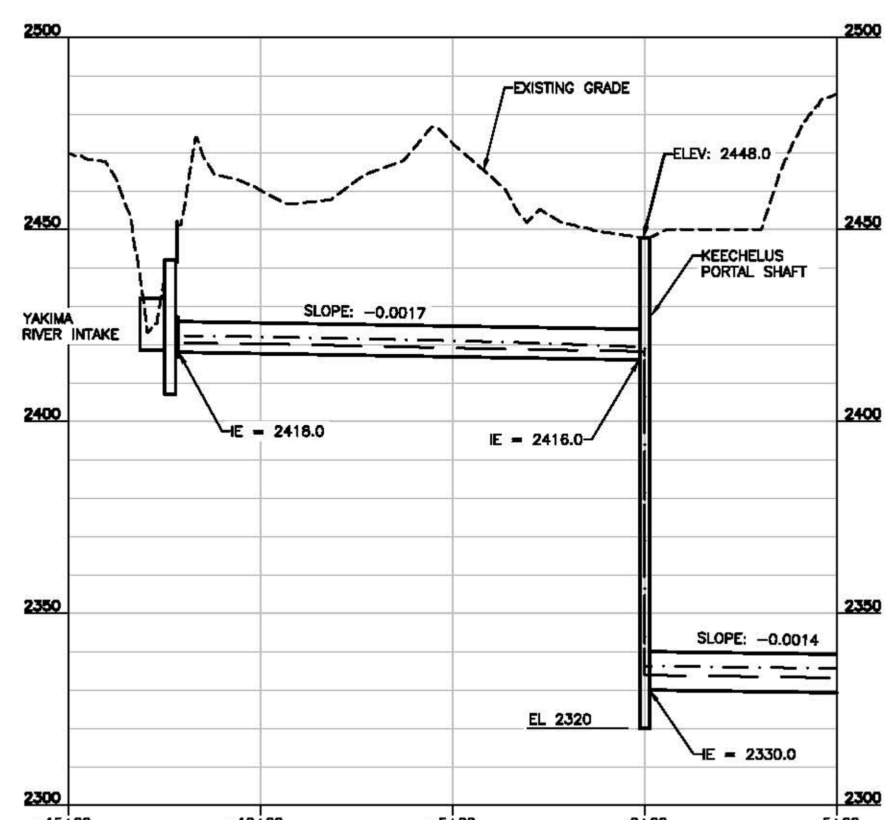
PROFILE

SCALE: 1"=1000' H; 1"=25' V



PROFILE - OPTION A PIPELINE 1

SCALE: 1"=250' H; 1"=25' V



PROFILE - OPTION B PIPELINE 2

SCALE: 1"=250' H; 1"=25' V

HYDRAULIC DESIGN PARAMETERS

- DESIGN FLOW RATE: 400 CFS
- FISH LADDER FLOW: 20 CFS
- HYDRAULIC REQUIREMENTS:
  - GRAVITY FLOW WITH MIN FREEBOARD 0.18 TIMES INSIDE DIAMETER AND NOT LESS THAN 1.5 FEET.
  - MAX DESIGN FLOW VELOCITY: LESS THAN 20 FT/SEC (PREFERABLY LESS THAN 10 FT/SEC); FOR CONCRETE LINED TUNNELS LESS THAN 10 FT/SEC; FOR UNLINED TUNNELS LESS THAN 5 FT/SEC.
- RUGOSITY OF LINING OR INTERIOR SURFACE:
  - PIPELINES: 0.001 FT (ROUGH); 0.0002 FT (SMOOTH)
  - UNLINED BORED TUNNELS: 0.059 FT (ROUGH); 0.0061 FT (SMOOTH)
  - CONCRETE LINED BORED TUNNELS: 0.002 FT (ROUGH); 0.0003 FT (SMOOTH)
- FROUDE NUMBER: LESS THAN 0.7 (EXCEPT NEAR PLANNED FLOW DISCONTINUITIES AND DROPS)
- STANDARDS:
  - UNITED STATES BUREAU OF RECLAMATION (USBR). (1994). "DESIGN STANDARDS NO. 3 - WATER CONVEYANCE SYSTEMS", DS-3, SEPTEMBER 30.
- DESIGN CRITERIA:
  - HDR ENGINEERING, INC. (2014). "TECHNICAL MEMORANDUM: KEECHELUS-TO-KACHESS CONVEYANCE DESIGN CRITERIA, YAKIMA RIVER BASIN INTEGRATED WATER RESOURCE MANAGEMENT PLAN", PREPARED FOR U.S. BUREAU OF RECLAMATION, CONTRACT NO. 08CA10677A ID/IQ, JUNE (DRAFT).
- VERTICAL DATUM:
  - NAVD 88
  - ELEVATIONS ARE APPROXIMATE

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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Managing Water in the West

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH

REVIEWED J. PETERSON

YAKIMA, WA 2014-08-20

GRAVITY TUNNEL HYDRAULIC PROFILE

NORTH TUNNEL ALIGNMENT

1C-102

SHEET 3 OF 17

DATE AND TIME PLOTTED Not Plotted PLOTTED BY Not Plotted
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Managing Water in the West

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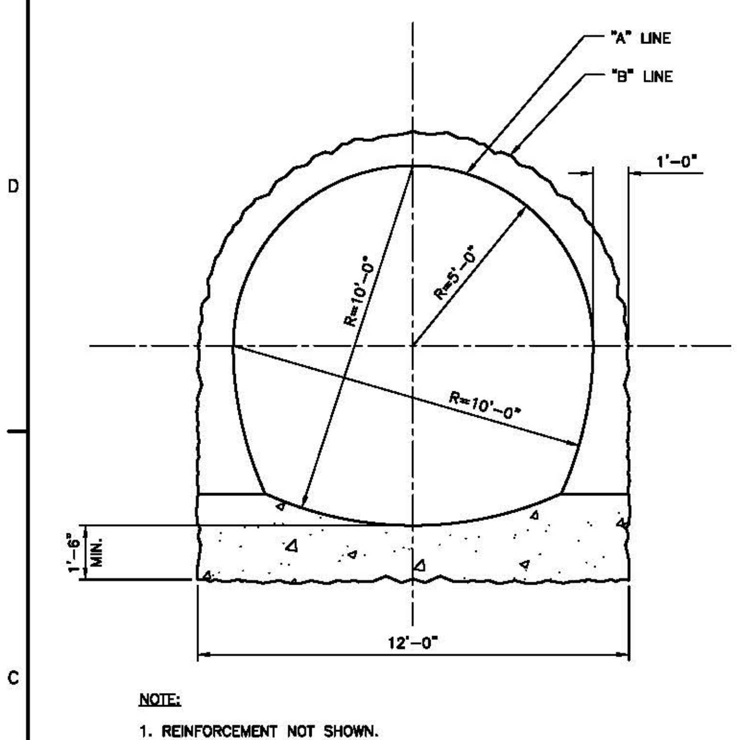
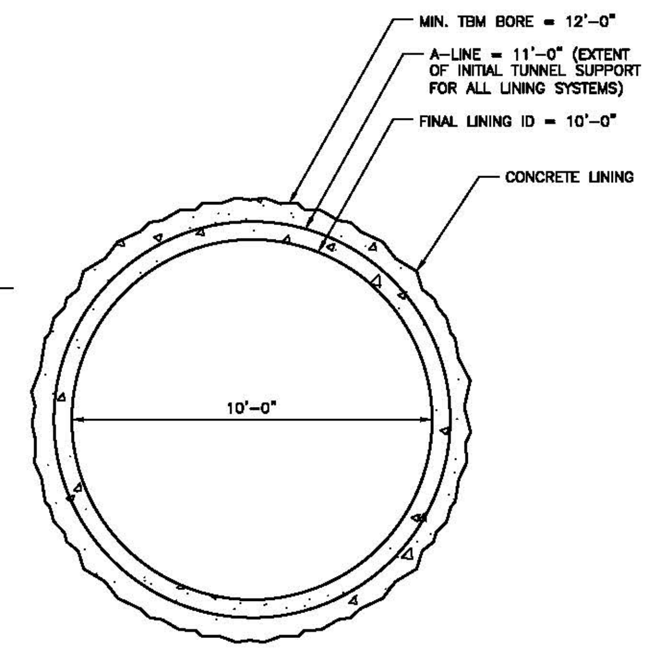


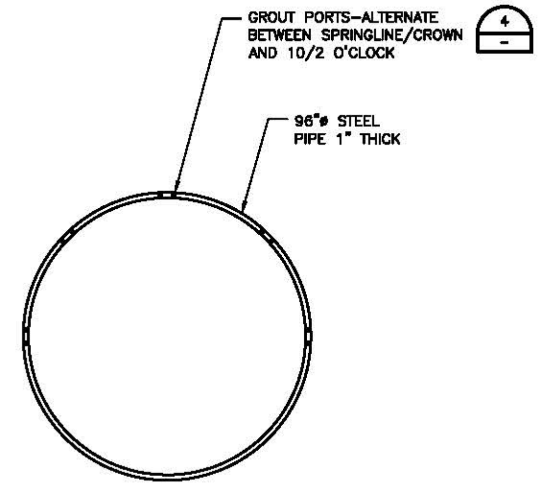
NOTE:

1. REINFORCEMENT NOT SHOWN.

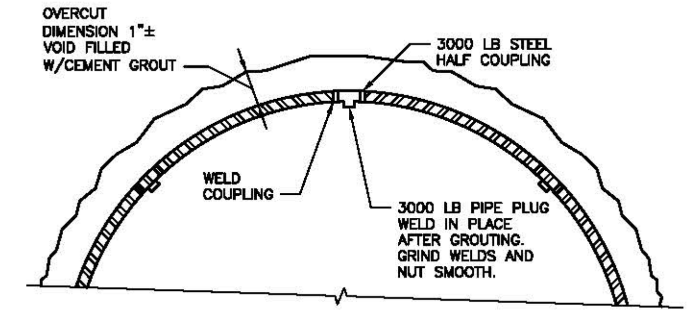
HORSESHOE TUNNEL SECTION (1/–)
SCALE: 3/8" = 1'-0"



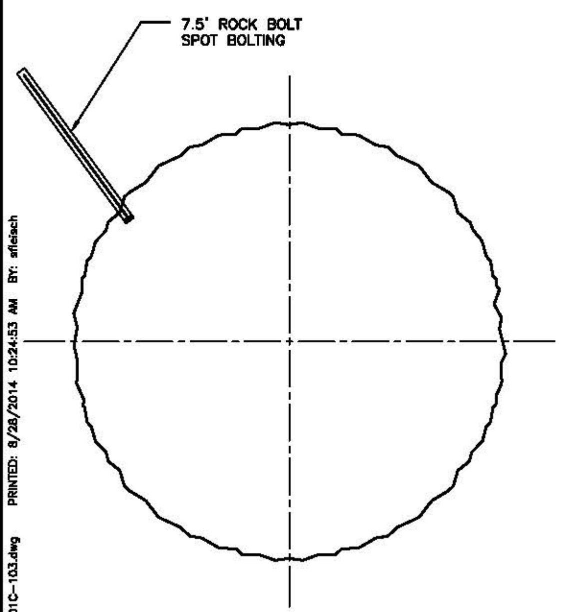
TBM TUNNEL SECTION (2/1C-101)
SCALE: 3/8" = 1'-0"



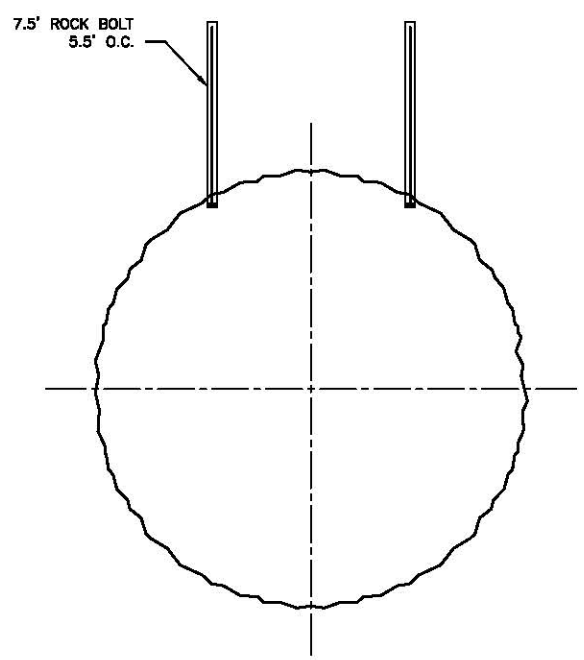
JACKED TUNNEL SECTION (3/1C-201)
SCALE: 3/8" = 1'-0"



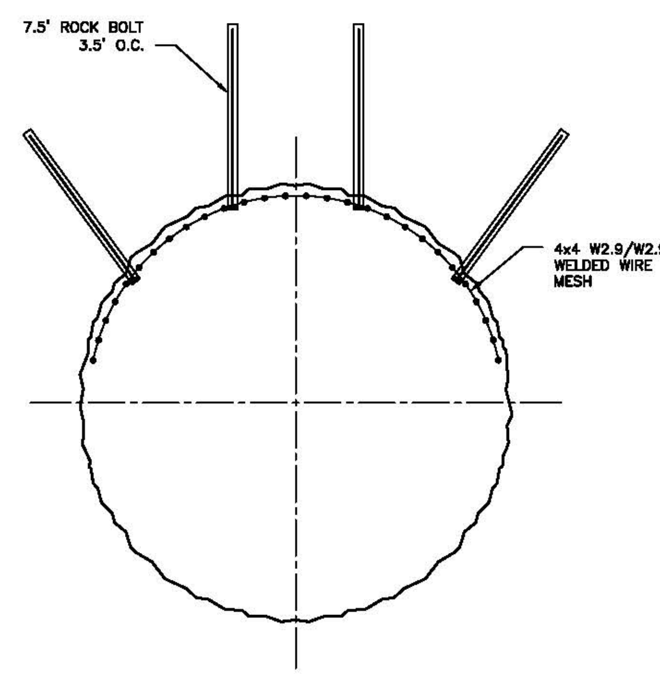
GROUT PORT DETAIL (4/–)
SCALE: NTS



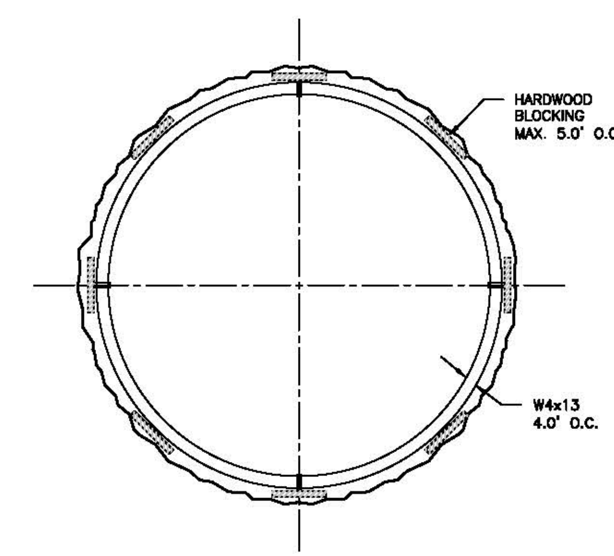
CLASS I SUPPORT
TBM TUNNEL SECTION (5/1C-101)
SCALE: 3/8" = 1'-0"



CLASS II SUPPORT
TBM TUNNEL SECTION (6/1C-101)
SCALE: 3/8" = 1'-0"



CLASS III SUPPORT
TBM TUNNEL SECTION (7/1C-101)
SCALE: 3/8" = 1'-0"



CLASS IV SUPPORT
TBM TUNNEL SECTION (8/1C-101)
SCALE: 3/8" = 1'-0"

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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BUREAU OF RECLAMATION
YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. BALLAGEER

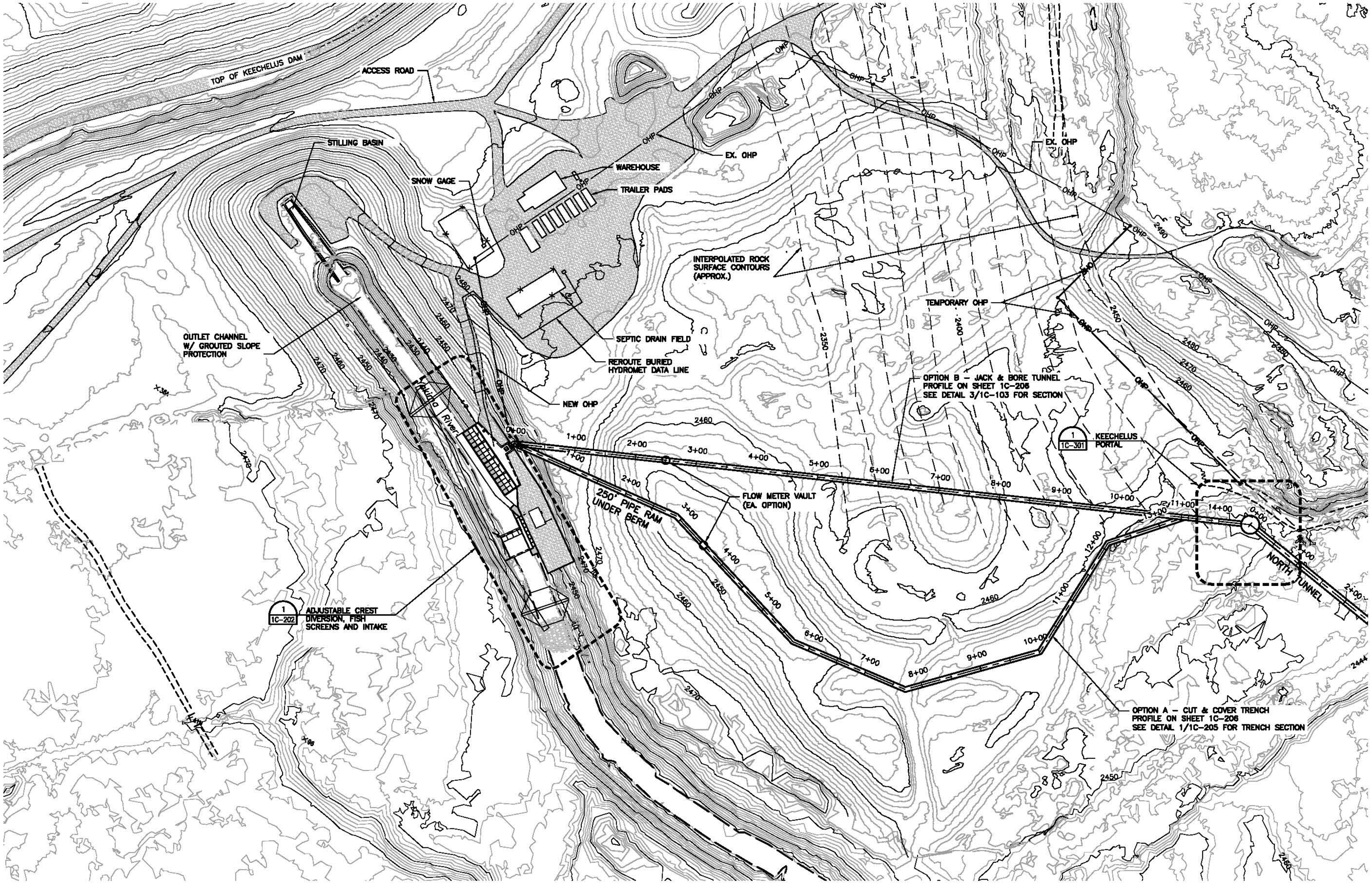
REVIEWED J. PETERSON

YAKIMA, WA 2014-08-20

GRAVITY TUNNEL TYPICAL SECTIONS

NORTH TUNNEL ALIGNMENT

1C-103



NOTE:

1. CONTOURS ARE BASED ON TWO FILES DATED 2000 AND 2007. DISCREPANCIES IN DATUM HAVE BEEN NOTED AND REQUIRE RESOLUTION BY A SURVEYOR.

SITE PLAN

0 40 80 160

SCALE IN FEET

N

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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Managing Water in the West

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KEITH GOSS STATE OF WASHINGTON 32146 REGISTERED PROFESSIONAL ENGINEER

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED K. GOSS

REVIEWED J. PETERSON

YAKIMA, WA 2014-08-20

KEECHELUS DIVERSION AREA SITE PLAN

NORTH TUNNEL ALIGNMENT

1C-201

SHEET 5 OF 17

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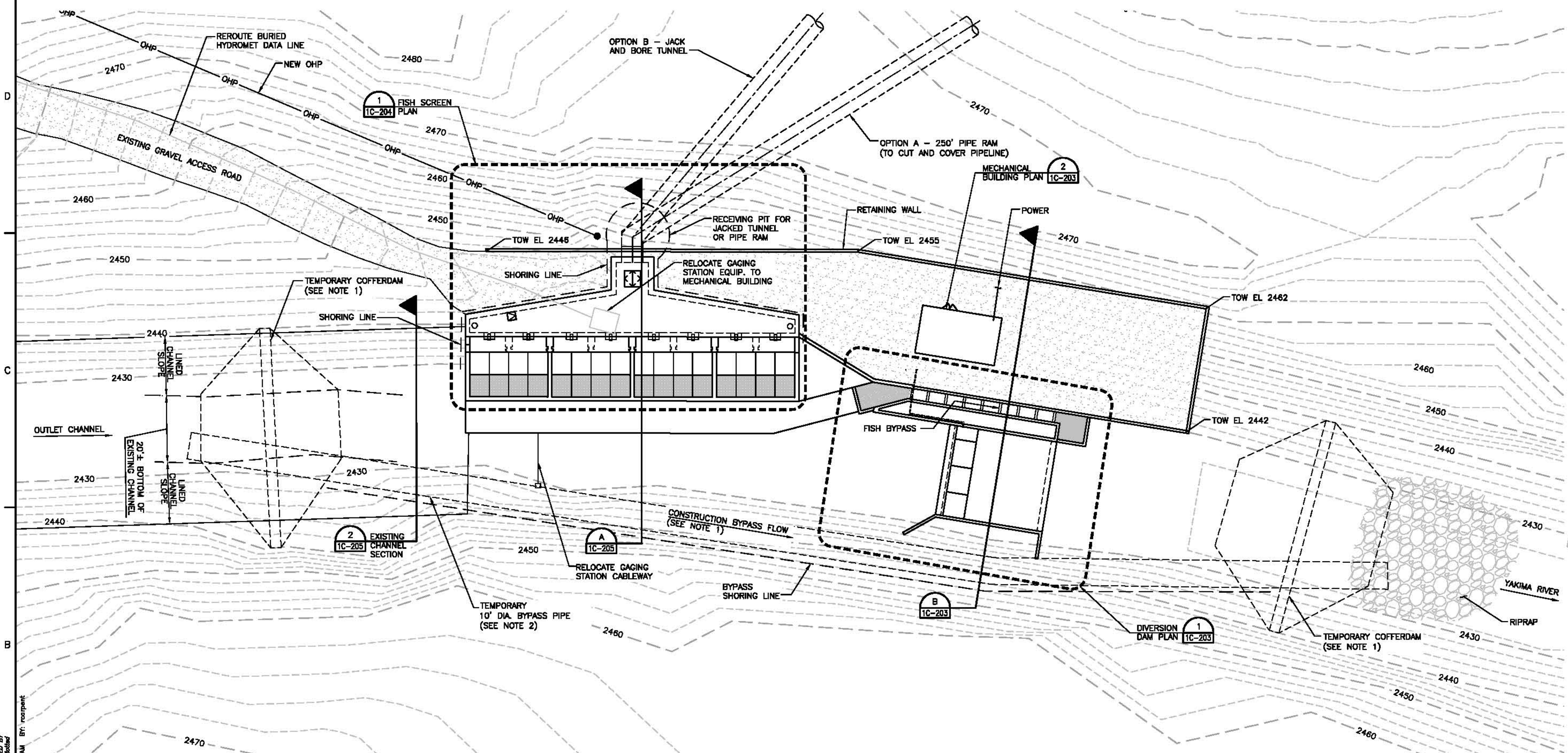

DESIGN CRITERIA

- MAXIMUM DIVERSION: 400 CFS
- MINIMUM POOL DEPTH: 7.0 FT
- SCREEN AREA: 1,150 SQ FT (4 BAYS, 29.25 FT LONG x 9.92 FT WIDE EACH)
- MAXIMUM APPROACH VELOCITY: 0.40 FPS
- MINIMUM 0.8 FPS SWEEPING FLOW
- AUTOMATED AIR BURST CLEANING

DIVERSION & INTAKE SITE PLAN 1 –

0 10 20 40
SCALE IN FEET

NOTES:

1. COFFERDAM AND RIVER BYPASS TO BE IMPLEMENTED BY CONTRACTOR. PIPE BYPASS IS ONE ALTERNATIVE. RELOCATION WILL BE REQUIRED DURING CONSTRUCTION TO ACCOMMODATE COMPLETION OF ADJUSTABLE CREST DIVERSION DAM AND SCREEN STRUCTURE.
2. BYPASS PIPE ALIGNMENT IS APPROXIMATE.

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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JOHN D. NELSON — STATE OF WASHINGTON — 36603 — REGISTERED PROFESSIONAL ENGINEER

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. NELSON
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER DIVERSION AND INTAKE SITE PLAN

NORTH TUNNEL ALIGNMENT

1C-202
SHEET 6 OF 17

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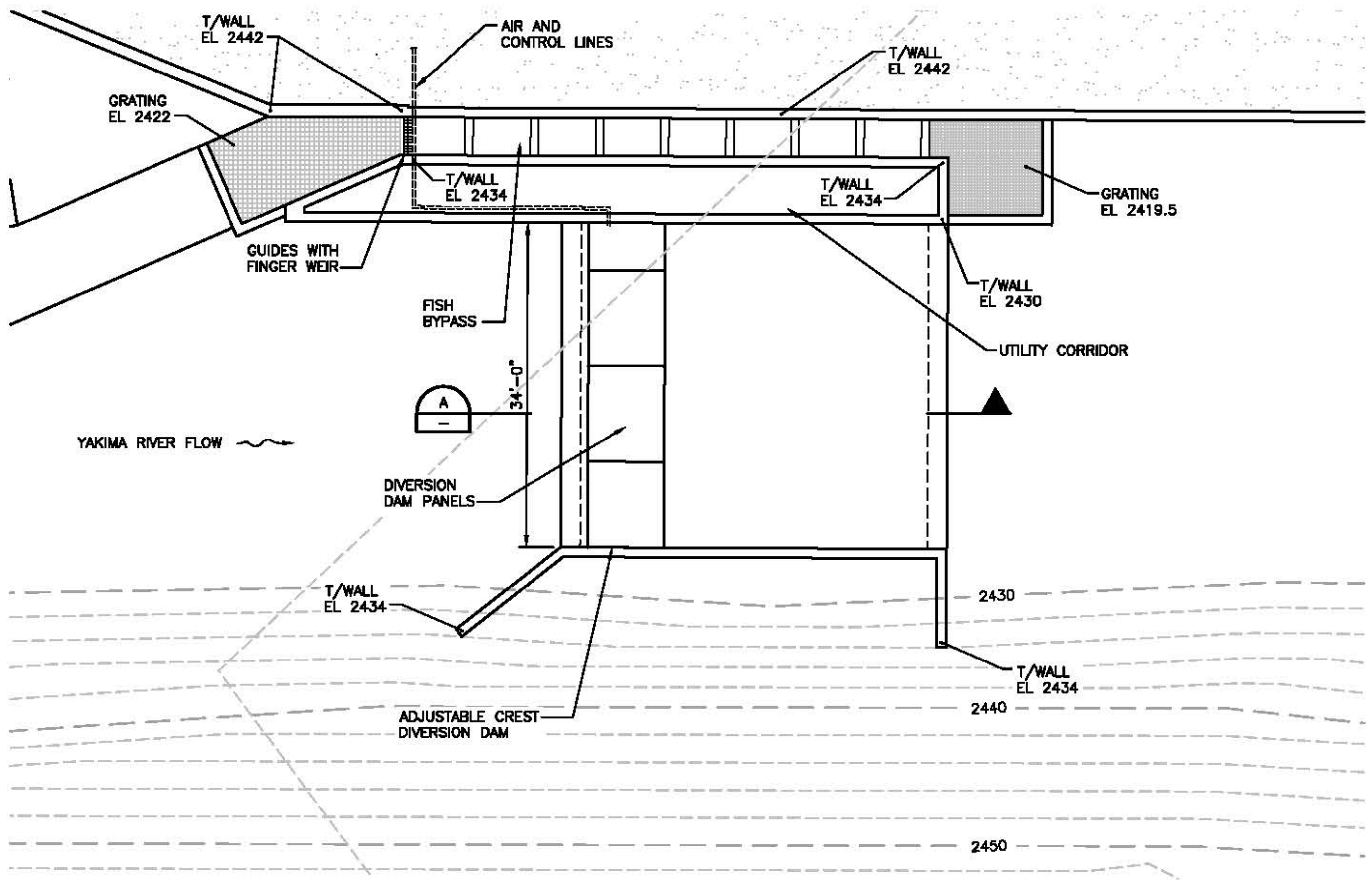
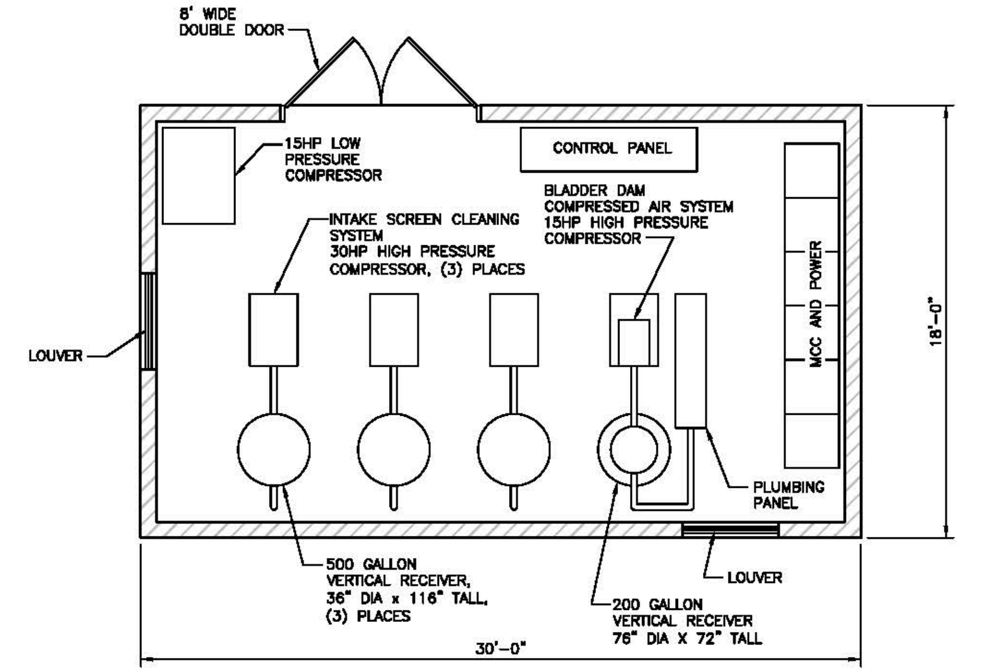
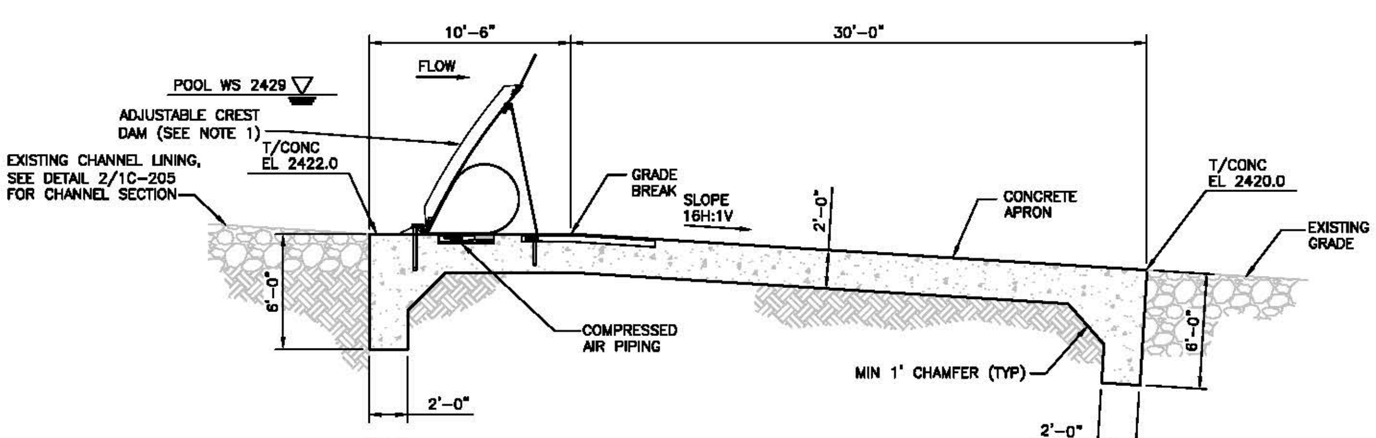


DIVERSION DAM PLAN
SCALE: 1"=10'
1
1C-202

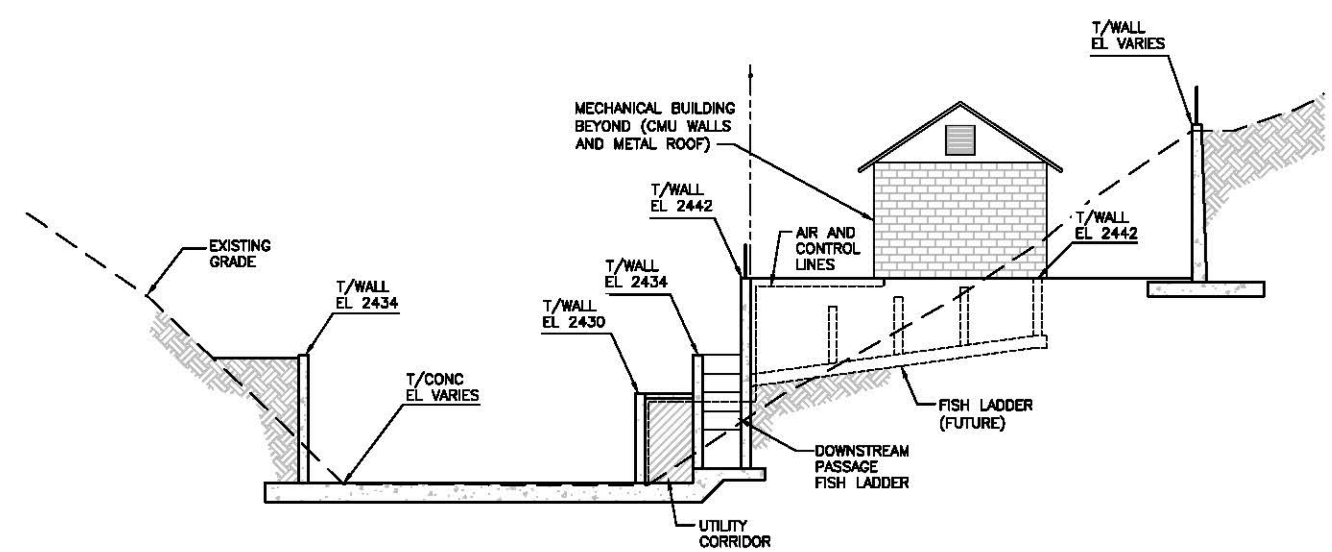


MECHANICAL BUILDING PLAN
SCALE: 1/4"=1'-0"
2
1C-202



NOTE:
1. INFLATABLE DAM SHOWN, BUT ANOTHER ADJUSTABLE DAM TYPE COULD BE USED.

DIVERSION DAM SECTION
SCALE: 1"=5'
A



DAM SECTION
SCALE: 1"=10'
B
1C-202

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. NELSON
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER DIVERSION DAM PLAN AND SECTION

NORTH TUNNEL ALIGNMENT

1C-203
SHEET 7 OF 17

DATE AND TIME PLOTTED Not Plotted
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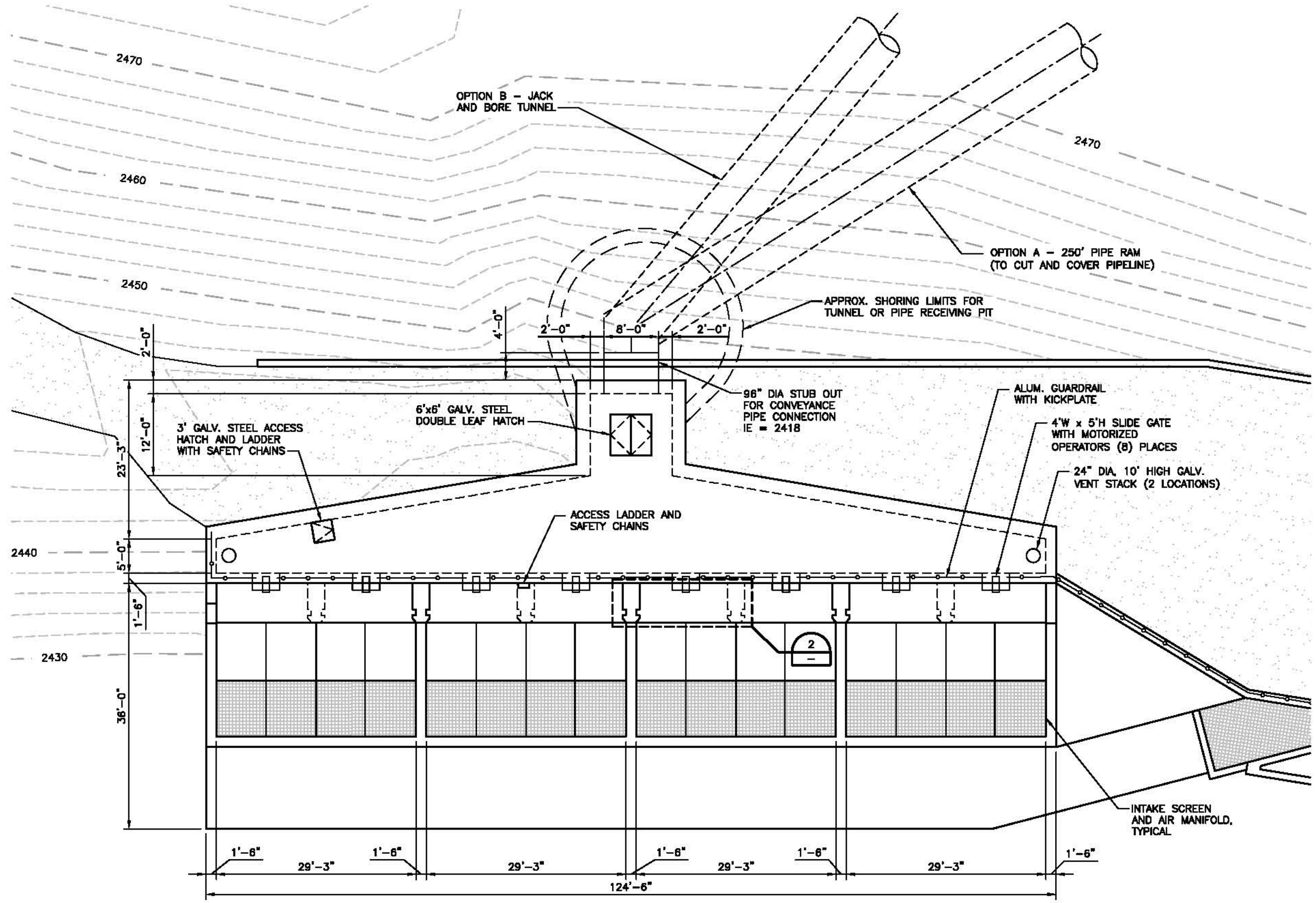
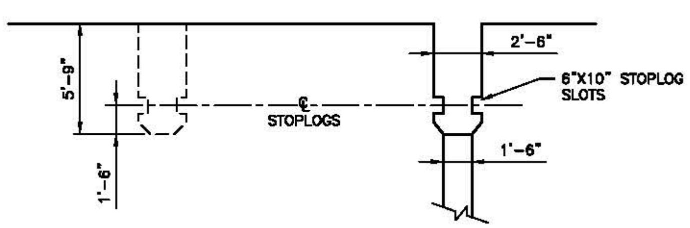


FISH SCREEN PLAN 1

0 5 10 20 SCALE IN FEET



FISH SCREEN PLAN 2

SCALE: 1" = 5'

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

J. NELSON — DESIGNED

J. PETERSON — REVIEWED

YAKIMA, WA — 2014-08-20

YAKIMA RIVER DIVERSION FISH SCREEN PLAN

NORTH TUNNEL ALIGNMENT

1C-204

SHEET 8 OF 17

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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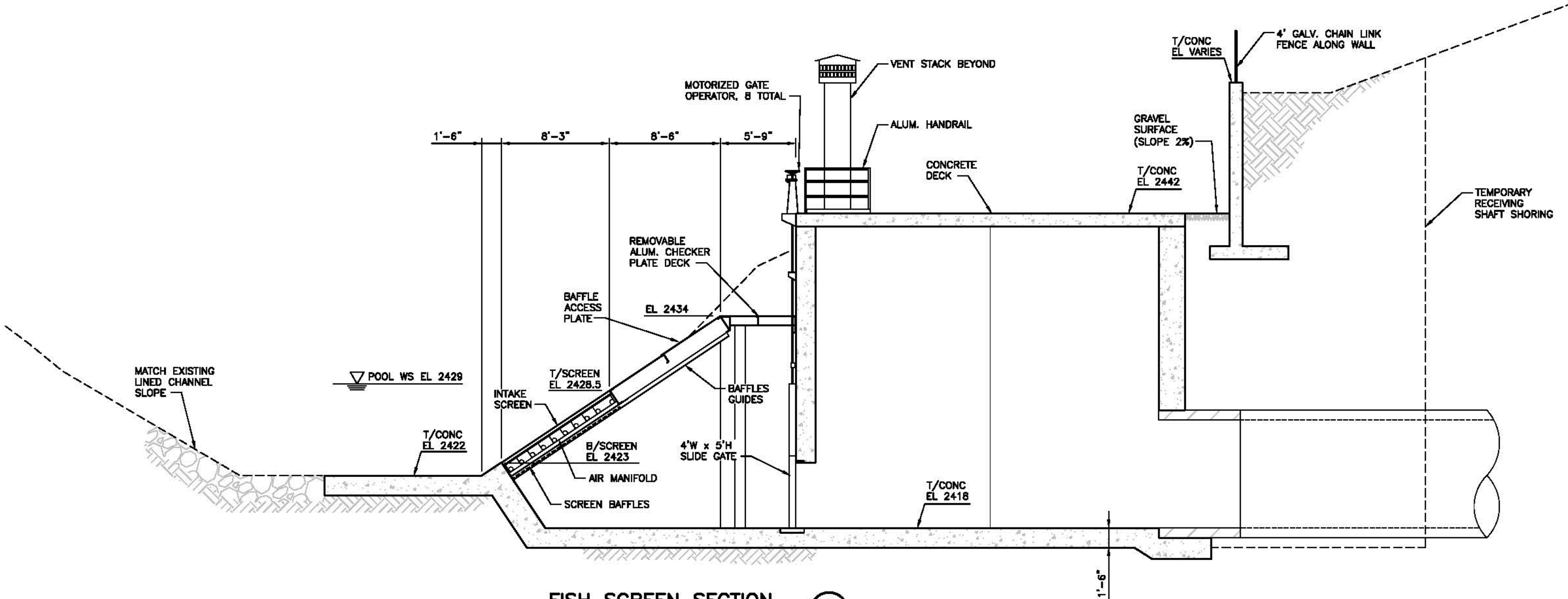
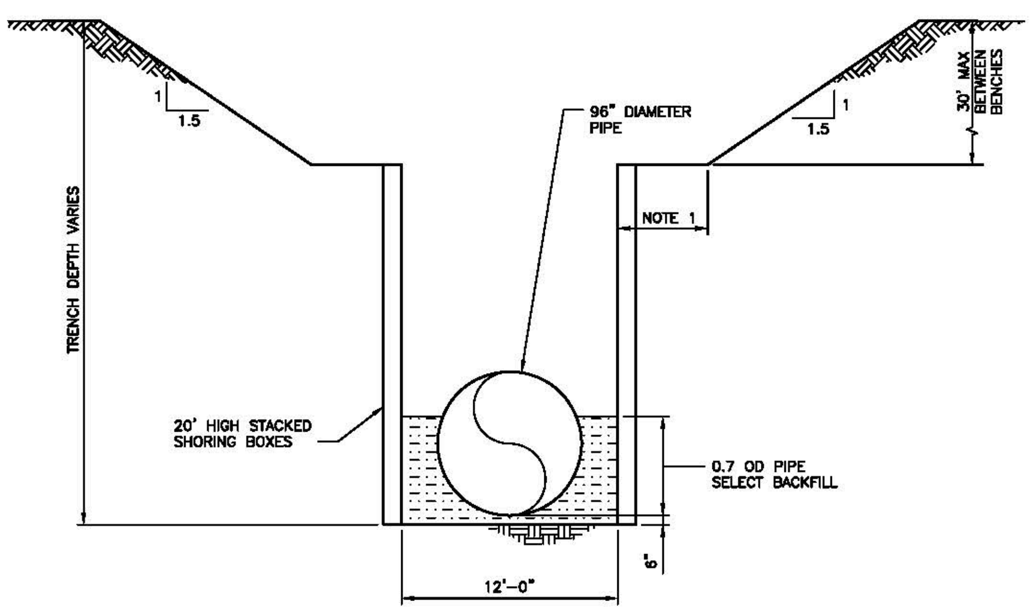
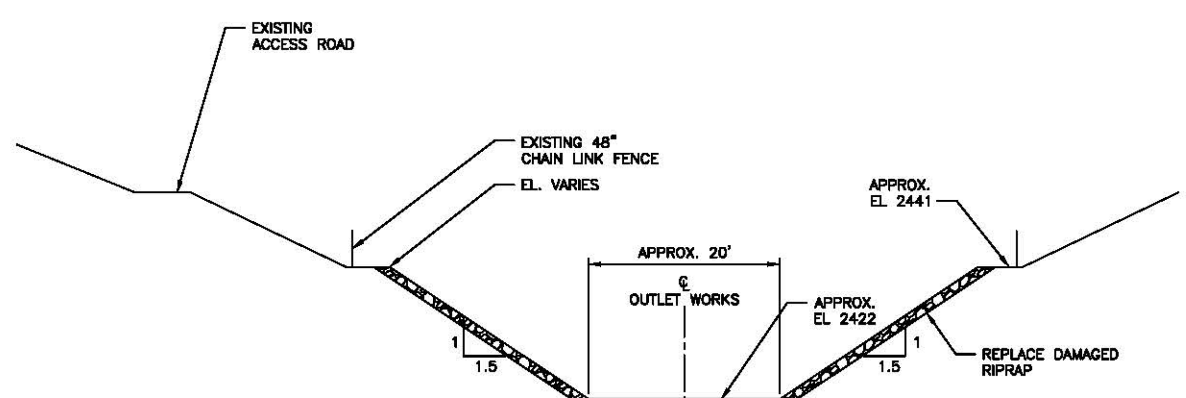


FISH SCREEN SECTION (A / 1C-202)
SCALE: 1"=5'



NOTE:
1. BENCH WIDTH AND CUT SLOPE TO BE DETERMINED BY GEOTECH.

OPTION A TRENCH SECTION – YAKIMA RIVER INTAKE TO KEECHELUS PORTAL (1 / VARIES)
SCALE: 3/16"=1'-0"



NOTE:
1. EXISTING CHANNEL SECTION IS BASED ON SECTION C–C FROM DRAWING 32–D–622, KEECHELUS DAM, OUTLET WORKS REHABILITATION, MARCH 17, 1976.

EXISTING CHANNEL SECTION (2 / 1C-202)
SCALE: NTS

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. NELSON
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YAKIMA, WA 2014–08–20

YAKIMA RIVER DIVERSION INTAKE DETAILS

NORTH TUNNEL ALIGNMENT

1C–205
SHEET 9 OF 17

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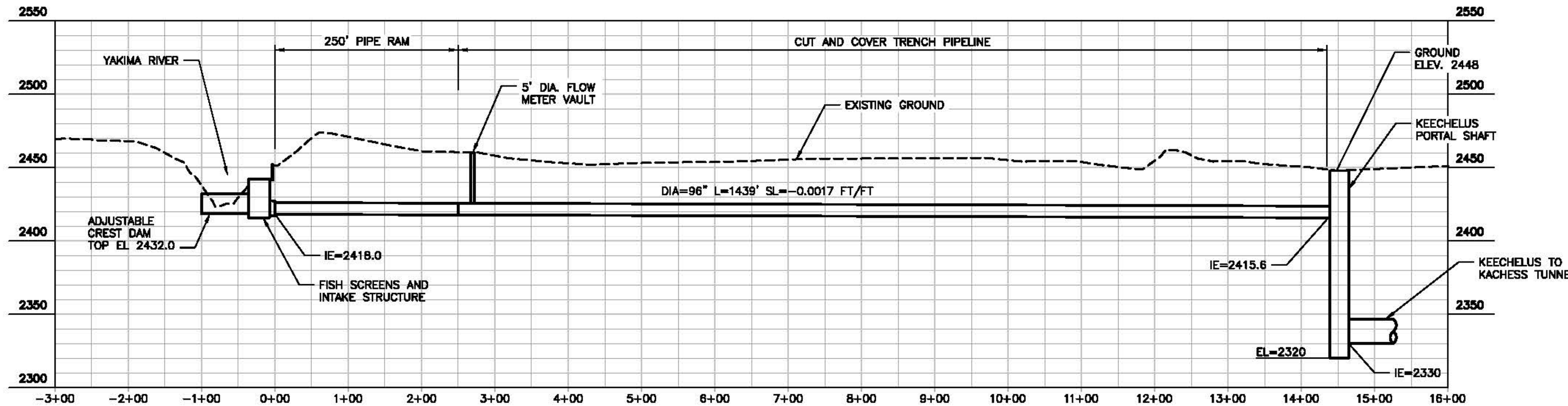
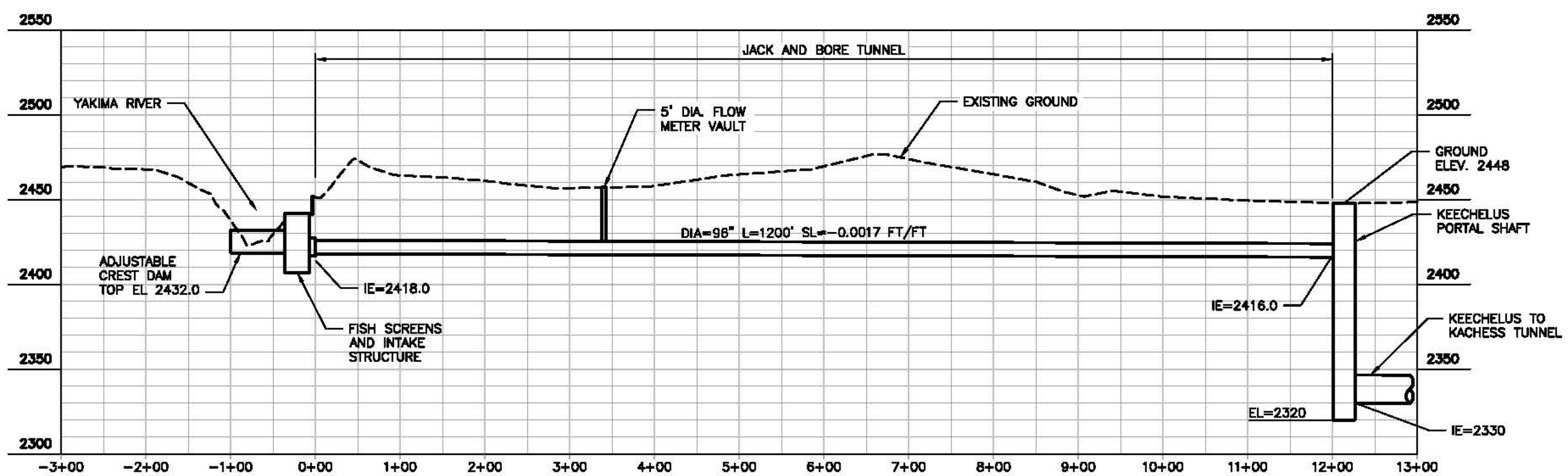


CUT & COVER TRENCH PIPELINE PROFILE – OPTION A

SCALE: 1"=100' H, 1"=50' V



TUNNEL PIPELINE PROFILE – OPTION B

SCALE: 1"=100' H, 1"=50' V

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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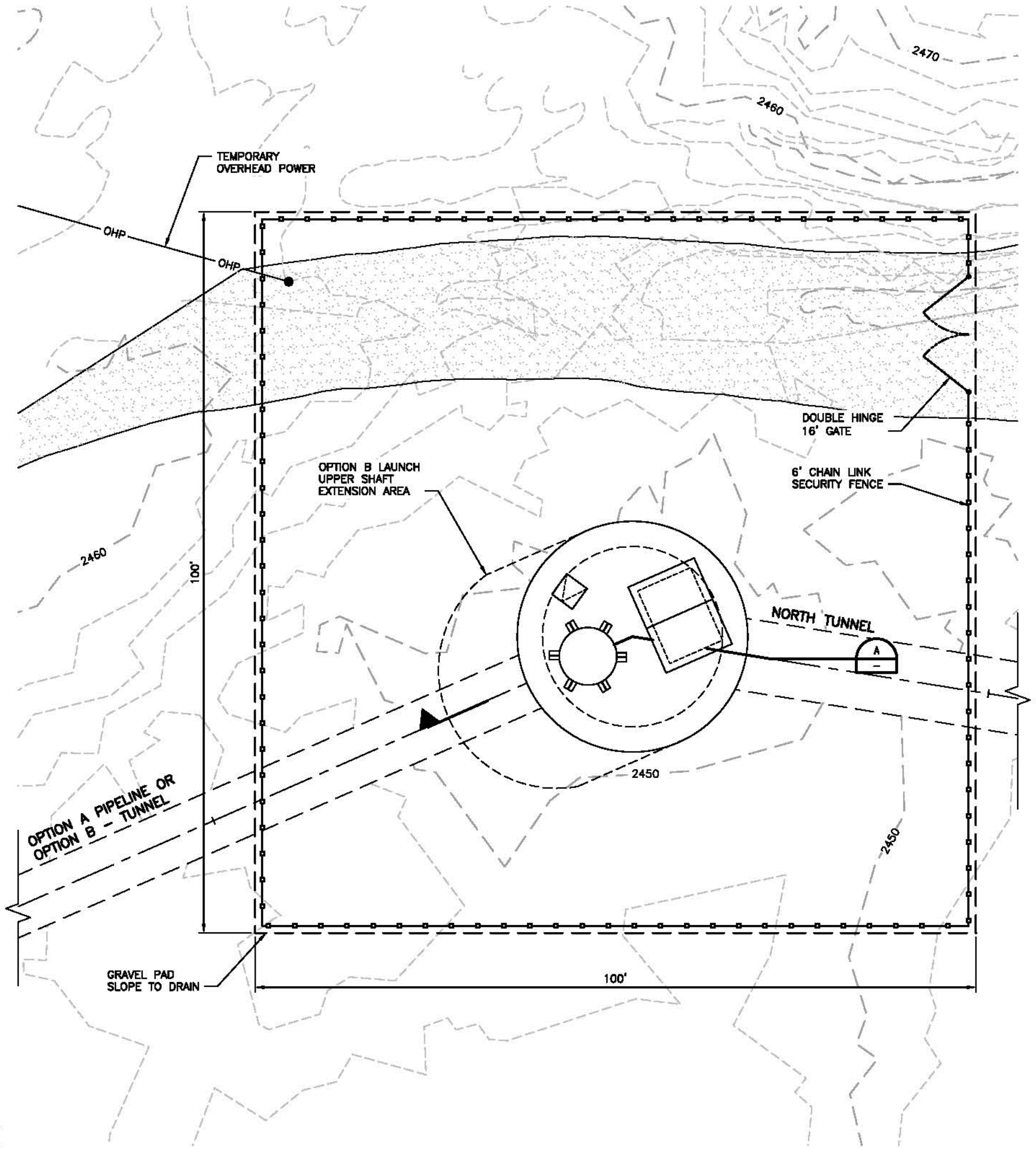
DESIGNED K. GOSS
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER INTAKE TO KEECHELUS PORTAL PROFILES

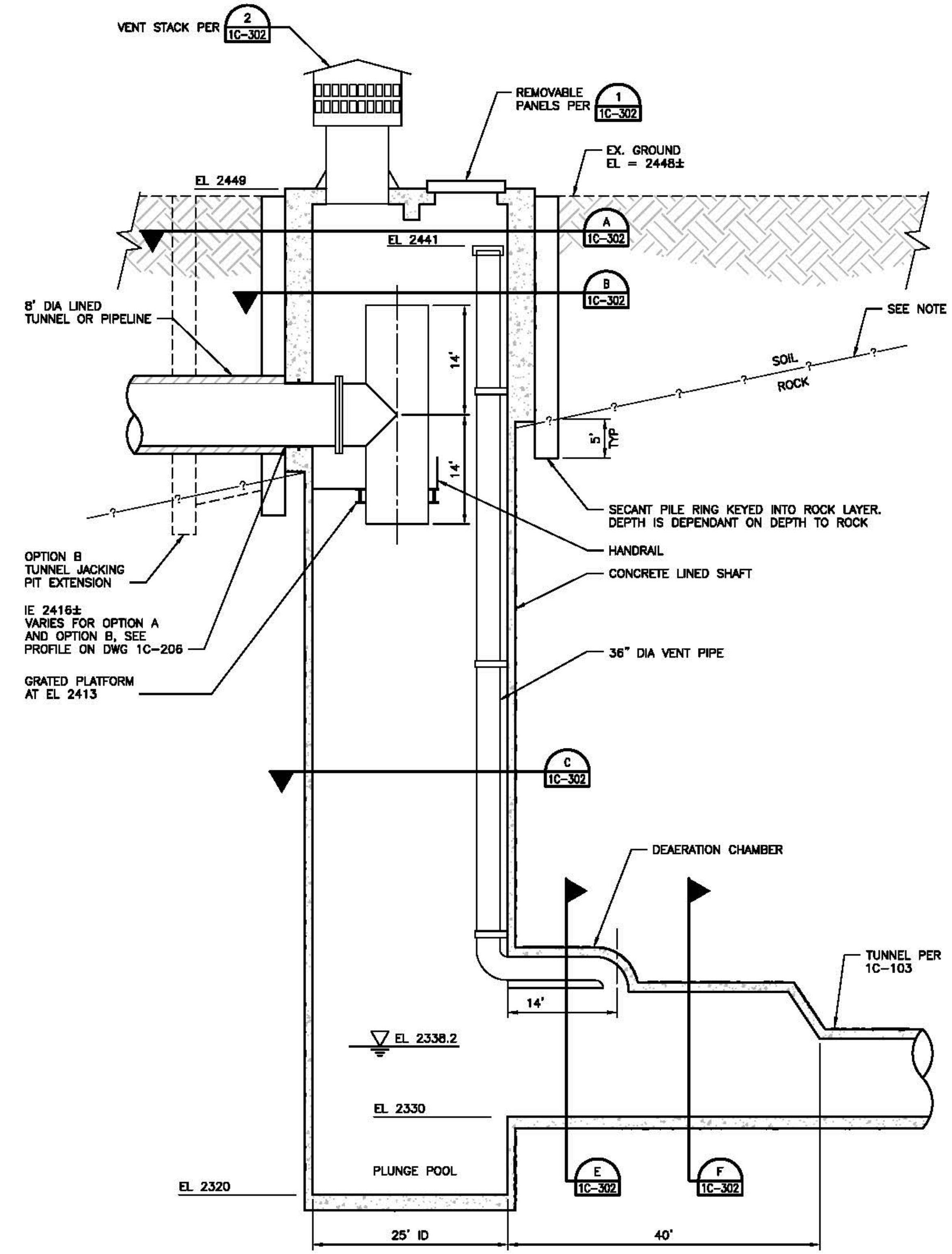
NORTH TUNNEL ALIGNMENT

1C-206
SHEET 10 OF 17



SITE PLAN 1 / 1C-201

0 5 10 20
SCALE IN FEET



NOTE:
1. ASSUMED ROCK CONTACT BASED ON LIMITED SUBSURFACE DATA.

KEECHELUS PORTAL SECTION A / –
SCALE: 1"=10'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

S. RAJAH
DESIGNED

J. PETERSON
REVIEWED

YAKIMA, WA 2014-08-20

KEECHELUS PORTAL SITE PLAN AND SECTION

NORTH TUNNEL ALIGNMENT

1C-301
SHEET 11 OF 17

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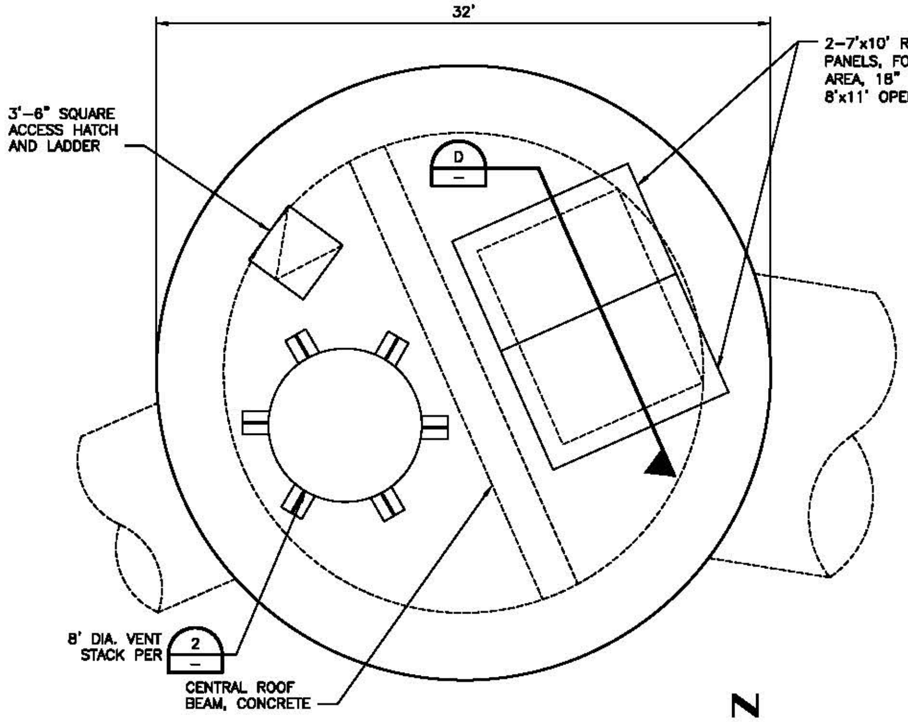
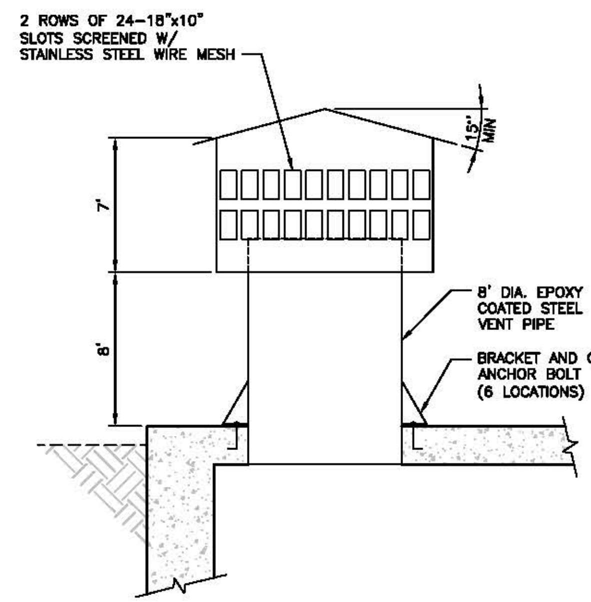
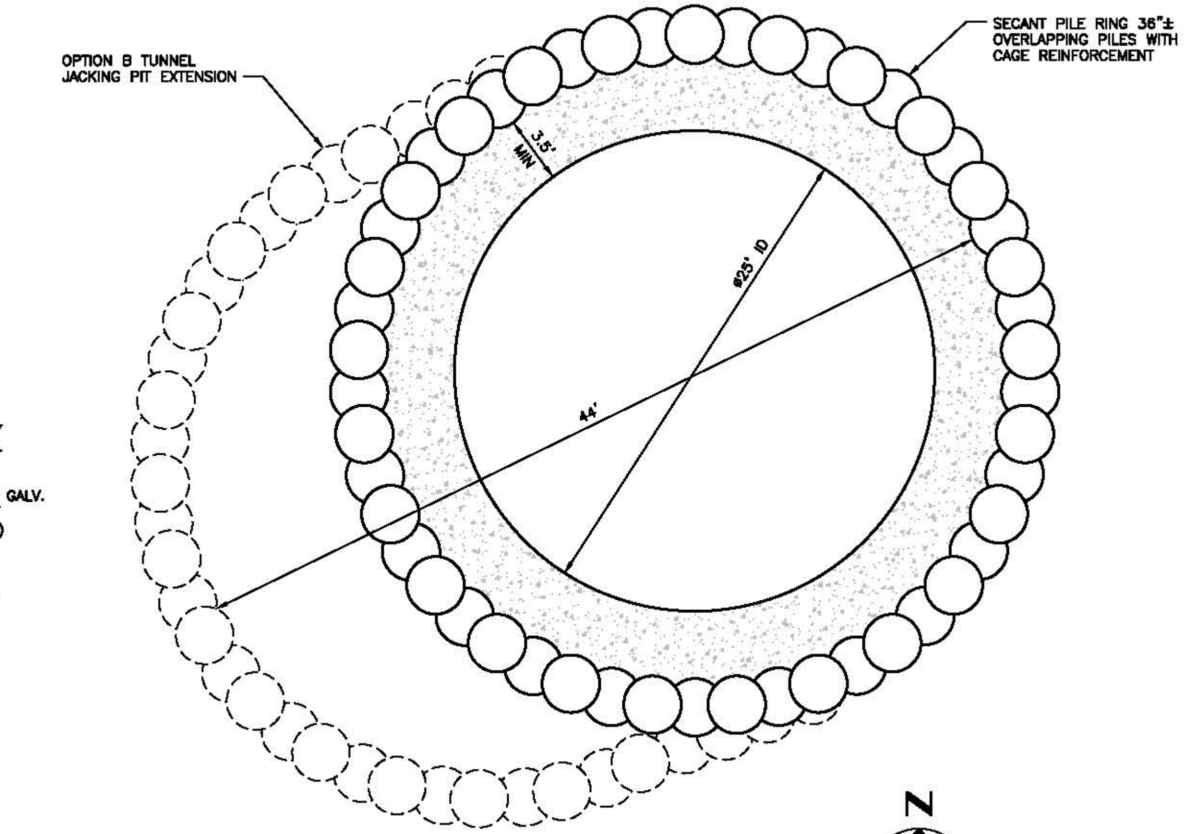


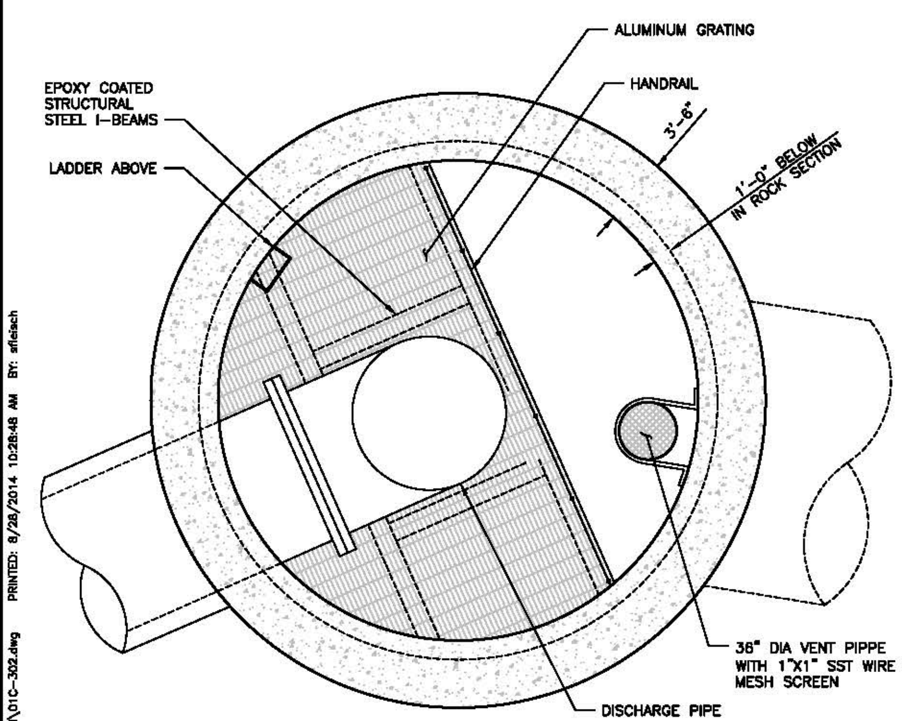
PORTAL SHAFT TOP SLAB PLAN (1)
SCALE: 1"=5'



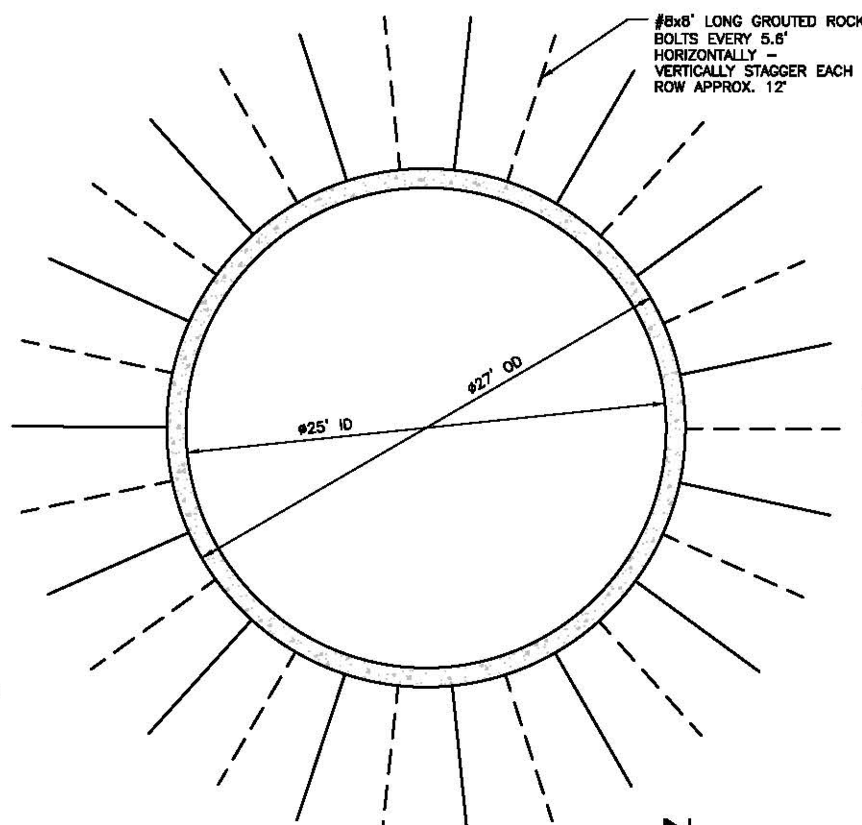
VENT STACK DETAIL (2)
SCALE: 1"=5'



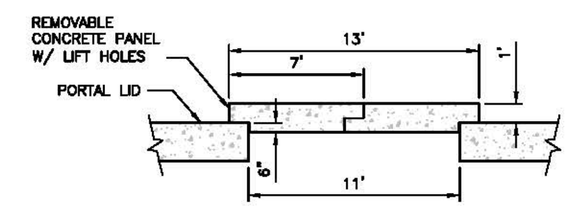
SOFT GROUND EXCAVATION SECTION (A / 1C-301)
SCALE: 1"=5'



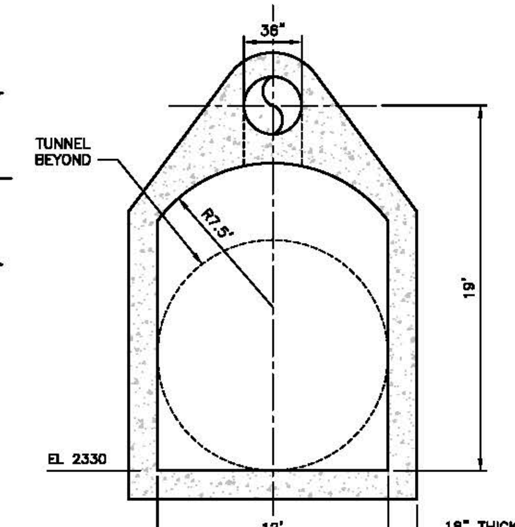
ELEVATION 2413 PLATFORM SECTION (B / 1C-301)
SCALE: 1"=5'



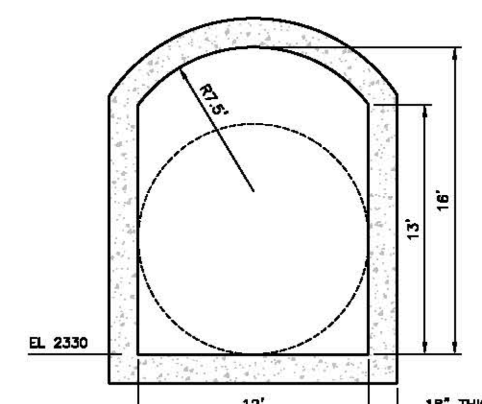
ROCK EXCAVATION SECTION (C / 1C-301)
SCALE: 1"=5'



REMOVABLE PANEL DETAIL (D)
SCALE: 1"=5'



DEAERATION CHAMBER SECTION (E / 1C-301)
SCALE: 1"=5'



DEAERATION CHAMBER SECTION (F / 1C-301)
SCALE: 1"=5'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

RECLAMATION
Managing Water in the West

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KANNIAH SRIBALASKANDARAJAH, STATE OF WASHINGTON, 34646, REGISTERED PROFESSIONAL ENGINEER

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED: S. RAJAH
REVIEWED: J. PETERSON
YAKIMA, WA 2014-08-20

KEECHELUS PORTAL SECTIONS AND DETAILS

NORTH TUNNEL ALIGNMENT

1C-302
SHEET 12 OF 17

DATE AND TIME PLOTTED: Not Plotted
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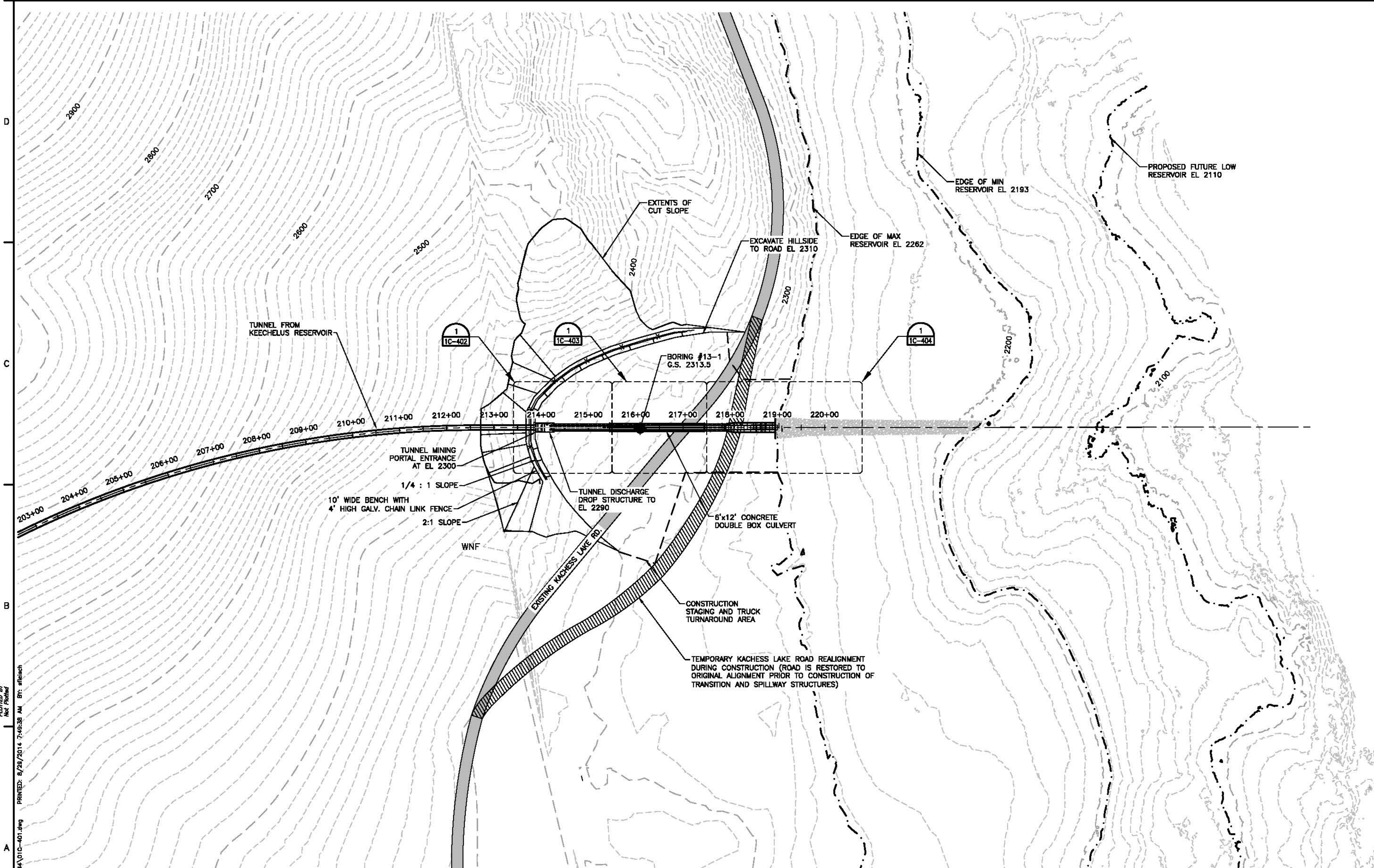

NOTE:

BENCHES AND SLOPES TO BE CONFIRMED BY GEOTECH.

PORTAL AND TEMPORARY ROAD SITE PLAN

0 50 100 200
SCALE IN FEET

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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BUREAU OF RECLAMATION
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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

K. GOSS
DESIGNED

J. PETERSON
REVIEWED

YAKIMA, WA 2014-08-20

KACHESS ROAD PORTAL SITE PLAN

NORTH TUNNEL ALIGNMENT

1C-401

SHEET 13 OF 17

DATE AND TIME PLOTTED Not Plotted
PLOTTED BY Not Plotted
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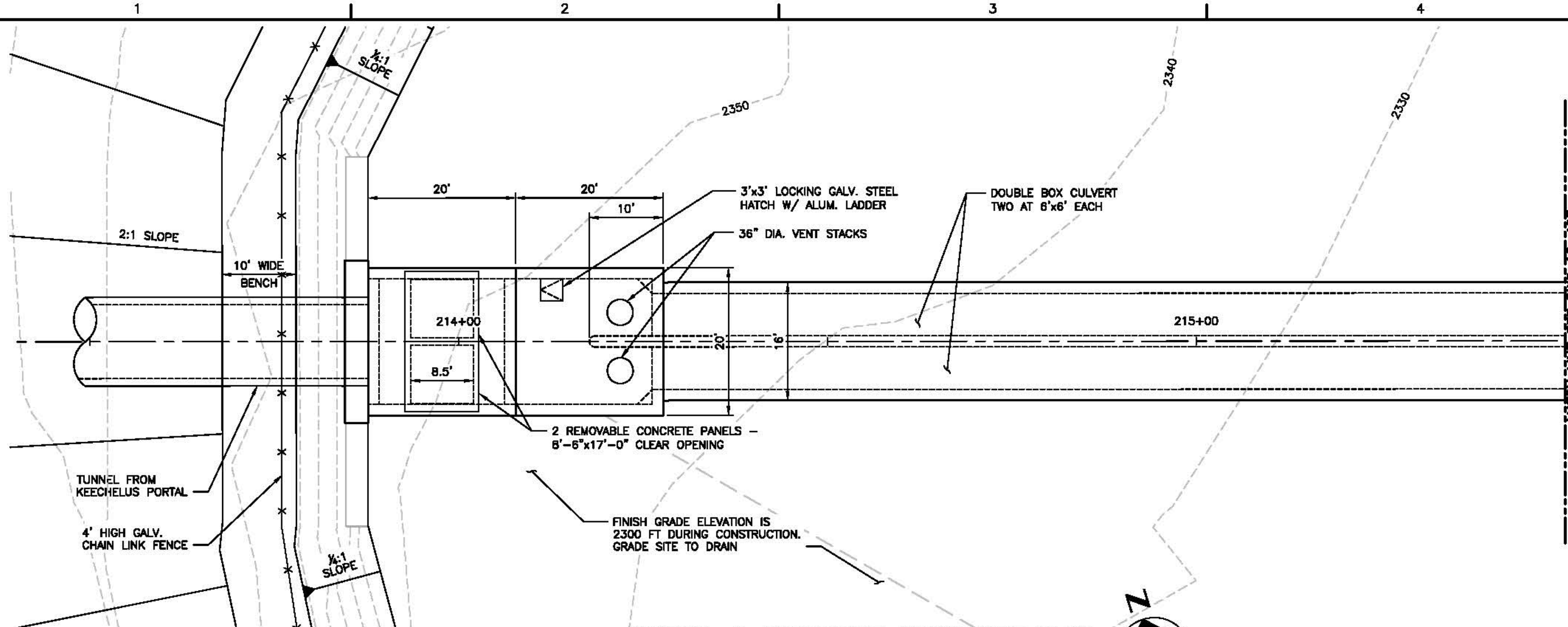
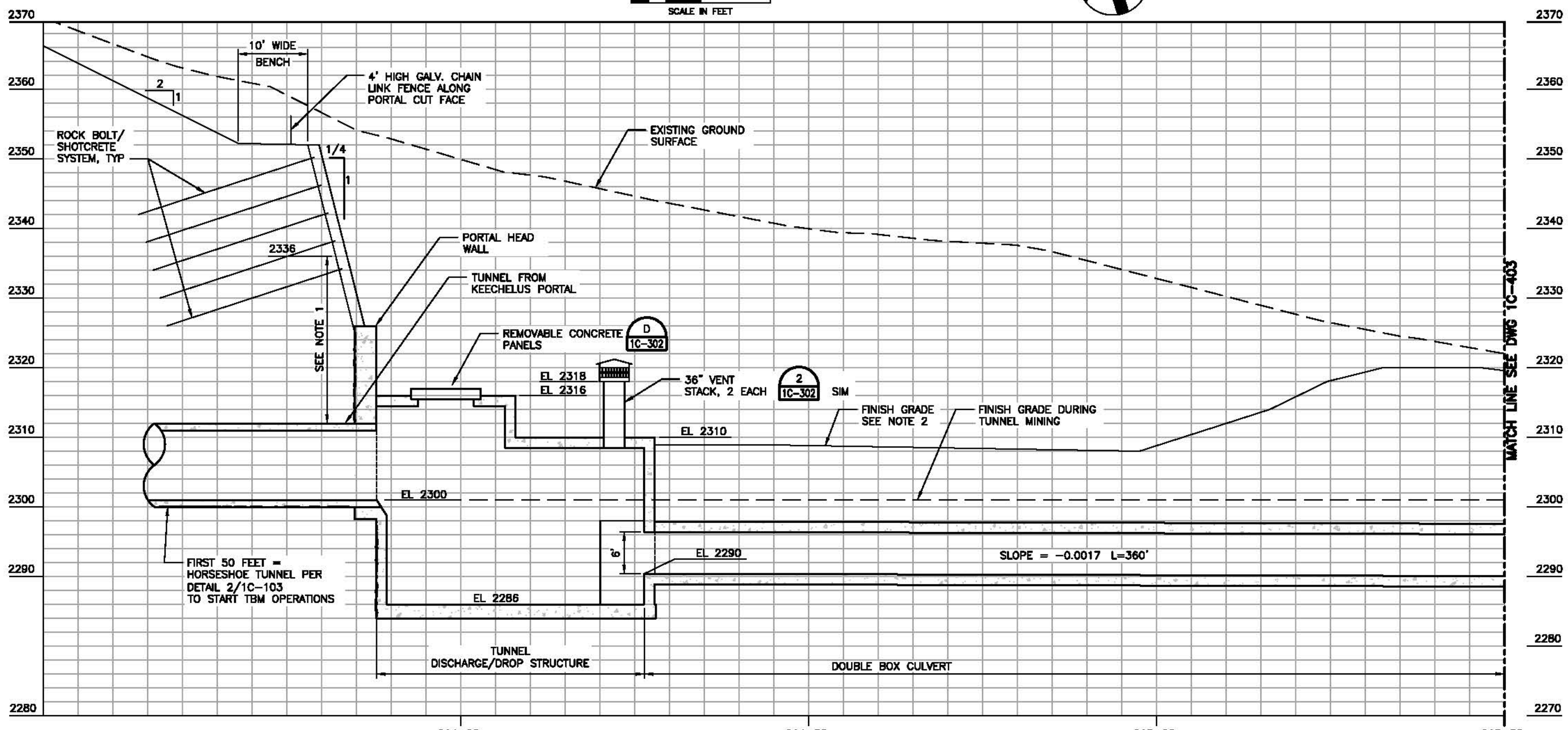


PORTAL & DISCHARGE STRUCTURE PLAN

0 5 10 20
SCALE IN FEET



PORTAL & DISCHARGE STRUCTURE PROFILE

SCALE: 1"=10' H & V

NOTES:

1. PROVIDE MINIMUM TWO TUNNEL DIAMETER OF ROCK ABOVE TUNNEL CROWN. THIS MAY REQUIRE RELOCATION OF PORTAL WALL.
2. FINISH GRADE AND SITE RESTORATION OF PORTAL SITE IS NOT YET DESIGNED.

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

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DESIGNED S. RAJAH
REVIEWED J. PETERSON
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KACHESS ROAD PORTAL AND DISCHARGE STRUCTURE PLAN AND PROFILE

NORTH TUNNEL ALIGNMENT

1C-402
SHEET 14 OF 17

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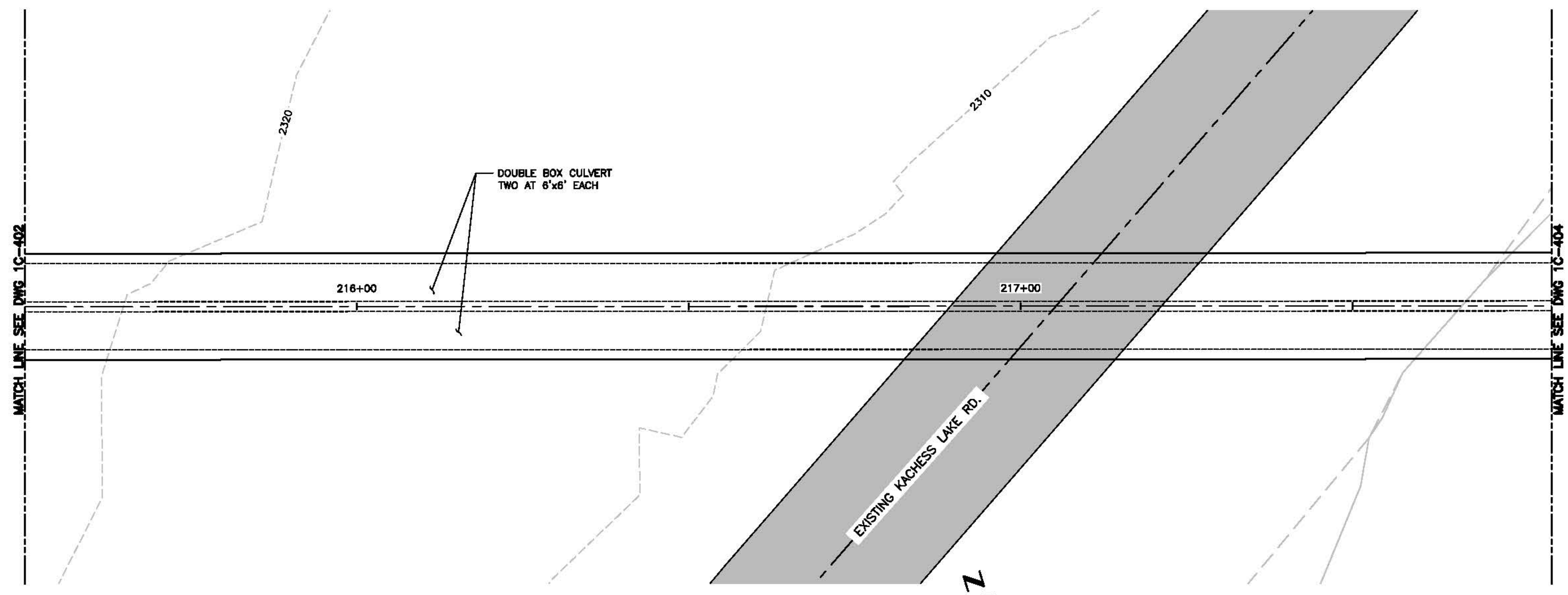
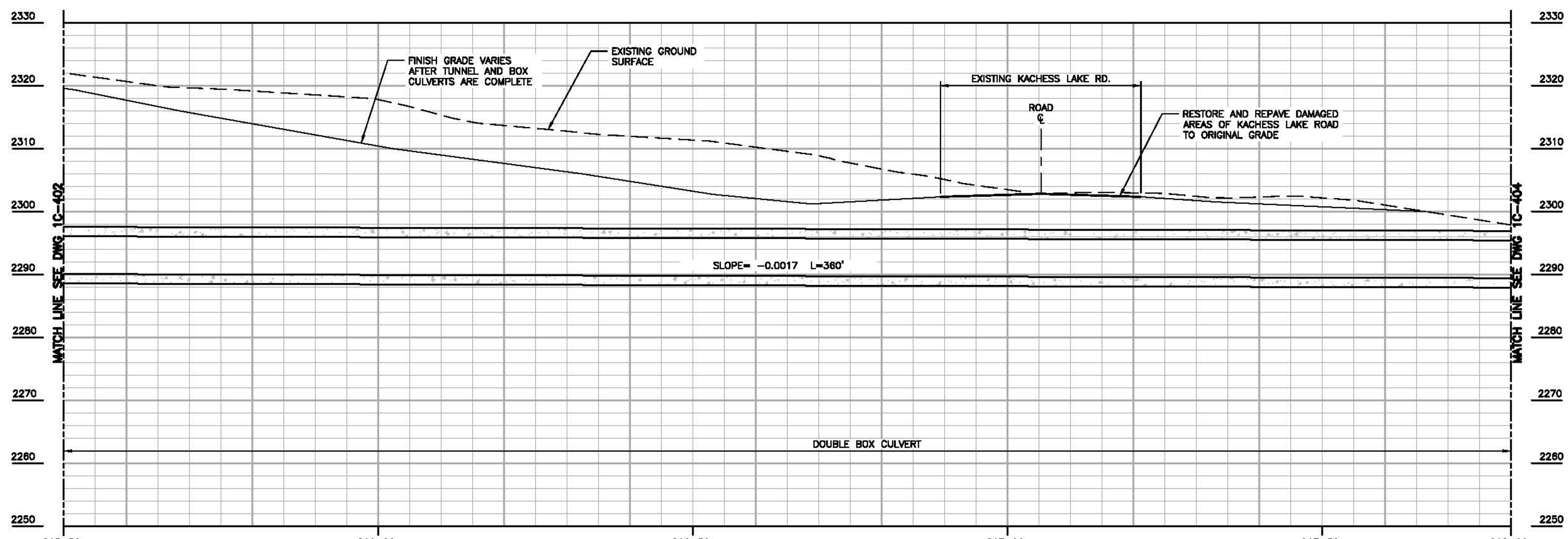


PORTAL & BOX CULVERT PLAN

0 5 10 20
SCALE IN FEET



PORTAL & BOX CULVERT PROFILE

SCALE: 1"=10' H & V

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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DESIGNED S. RAJAH

REVIEWED J. PETERSON

YAKIMA, WA 2014-08-20

KACHESS ROAD PORTAL AND BOX CULVERT PLAN AND PROFILE

NORTH TUNNEL ALIGNMENT

1C-403

SHEET 15 OF 17

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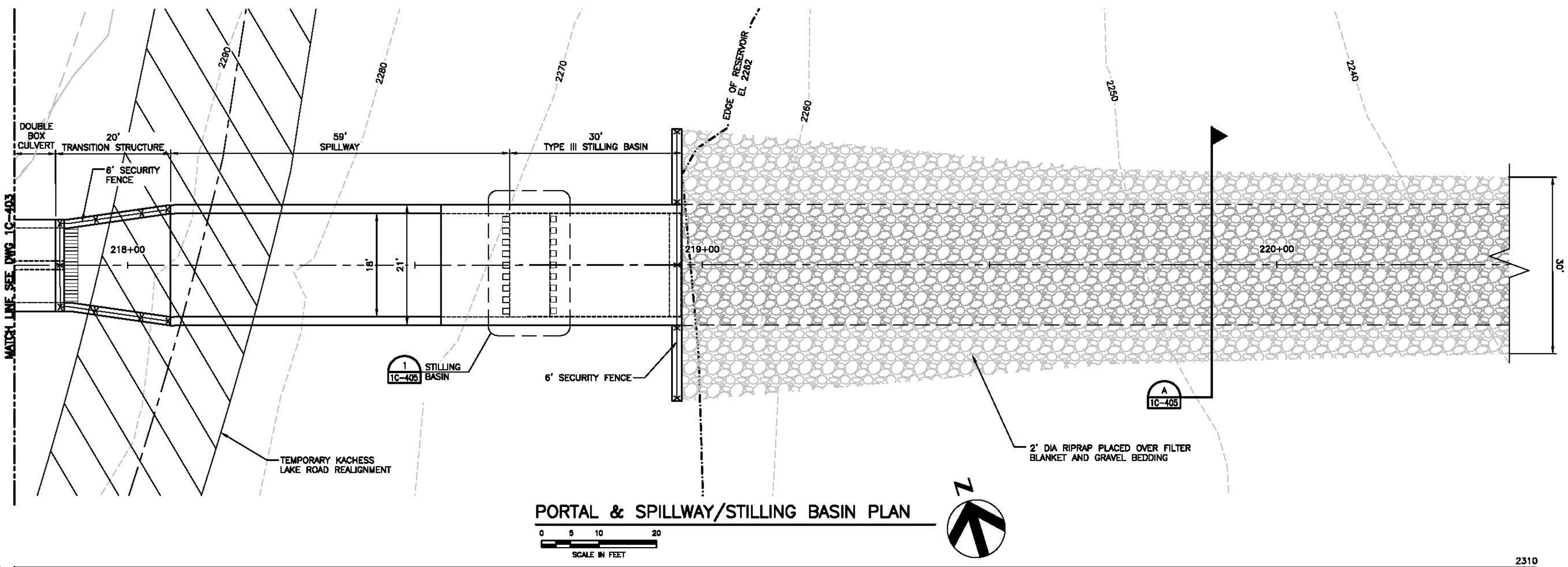
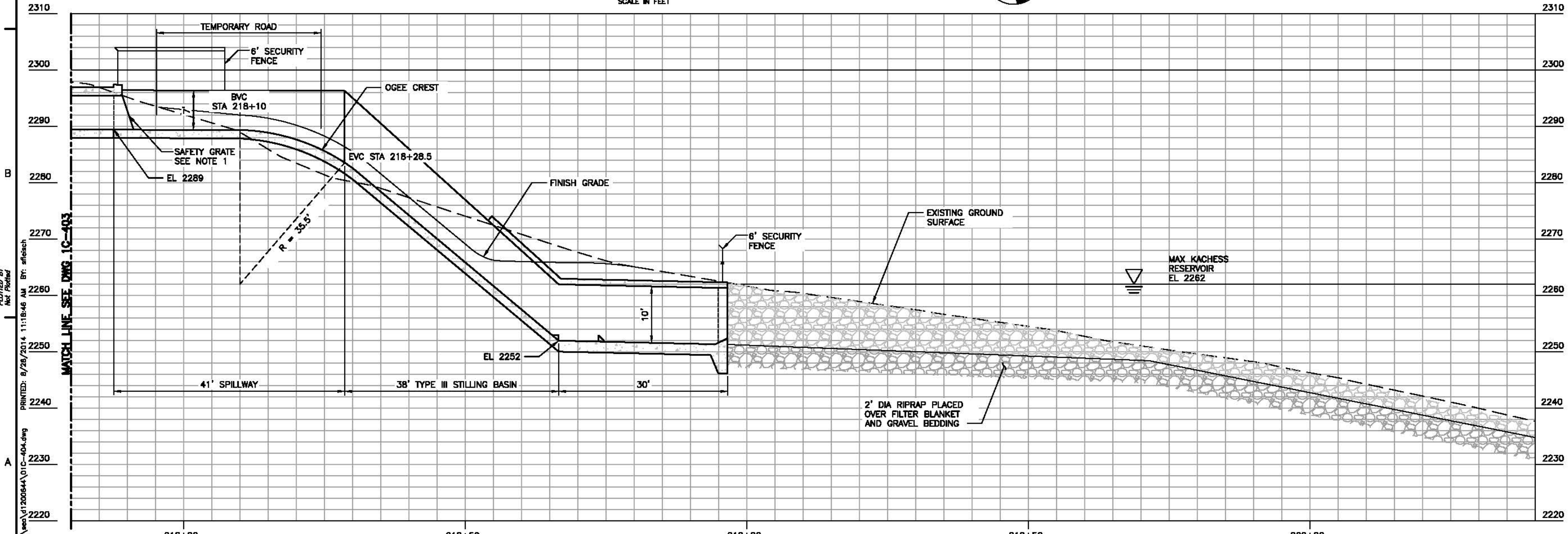


PORTAL & SPILLWAY/STILLING BASIN PLAN

0 5 10 20
SCALE IN FEET



NOTES:

1. SAFETY GRATE SIZED TO EXCLUDE ENTRY BY PEOPLE AND LARGE ANIMALS.

PORTAL & SPILLWAY/STILLING BASIN PROFILE

SCALE: 1"=10' H & V

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KANNAN SRIBALASKANDARAJAH STATE OF WASHINGTON 34049 REGISTERED PROFESSIONAL ENGINEER

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH

REVIEWED J. PETERSON

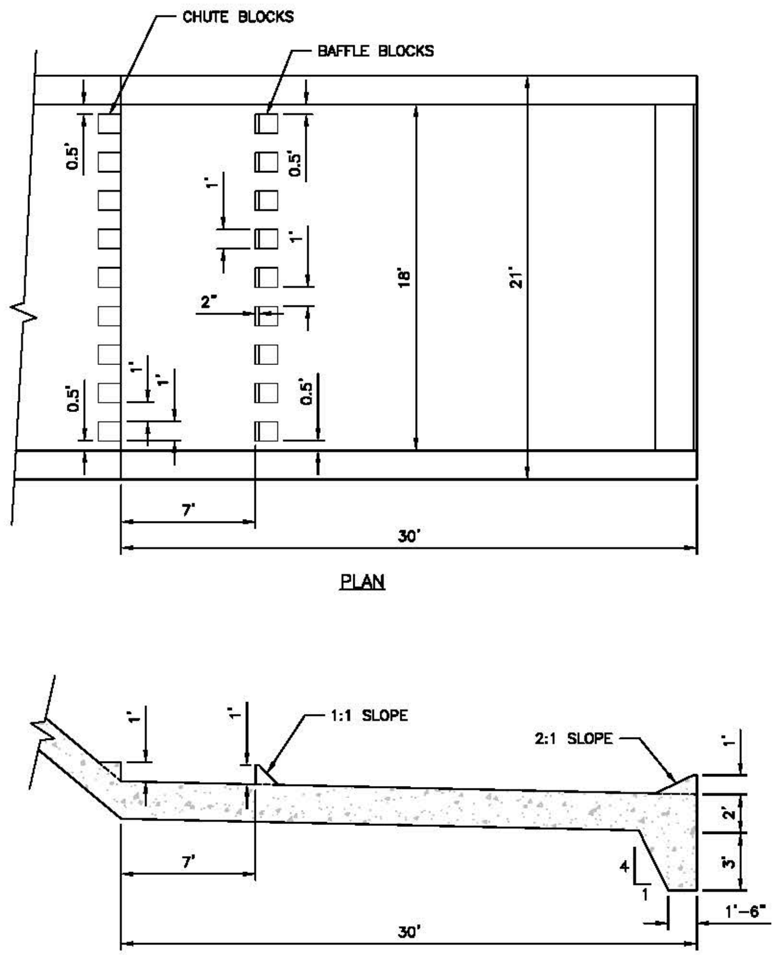
YAKIMA, WA 2014-08-20

KACHESS ROAD PORTAL SPILLWAY/STILLING BASIN PLAN AND PROFILE

NORTH TUNNEL ALIGNMENT

1C-404

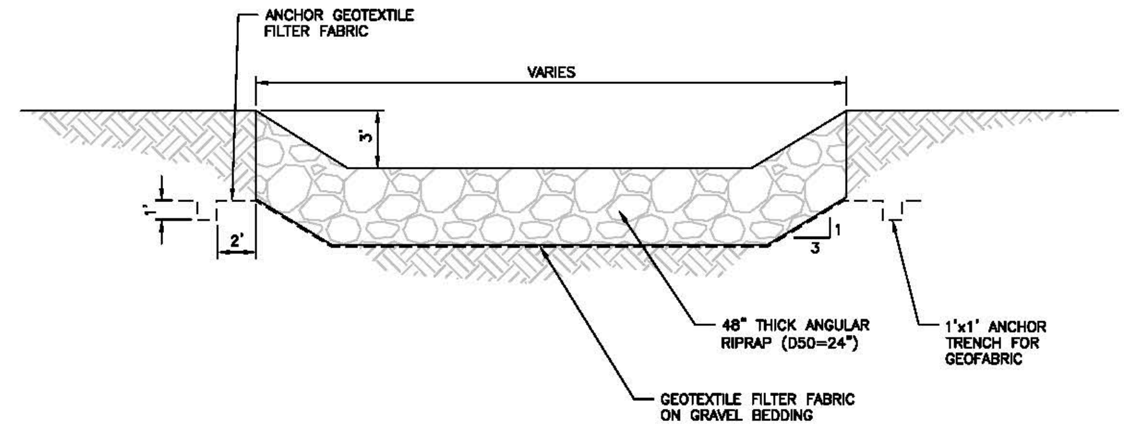
SHEET 16 OF 17



PLAN

SECTION

TYPE III STILLING BASIN DETAIL (1 / 1C-404)
SCALE: 1"=5'



NOTE:
THIS RIPRAP SECTION ASSUMES AN ERODIBLE SOIL SUBSTRATE BELOW THE STILLING BASIN.

RIPRAP SECTION (A / 1C-403)
SCALE: 1"=5'

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED: S. RAJAH
REVIEWED: J. PETERSON
YAKIMA, WA 2014-08-20

KACHESS ROAD PORTAL SPILLWAY/STILLING BASIN DETAILS

NORTH TUNNEL ALIGNMENT

1C-405
SHEET 17 OF 17

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Appendix B
South Tunnel Alignment Drawings

2G-001	Cover Sheet – Location Maps and Sheet Index
2C-101	Pressure & Gravity Tunnel Plan and Profile
2C-102	Pressure & Gravity Tunnel Hydraulic Profile
2C-103	Pressure & Gravity Tunnel Typical Sections
2C-201	Keechelus Diversion Area Site Plan
2C-202	Yakima River Diversion and Intake Site Plan
2C-203	Yakima River Diversion Dam Plan and Sections
2C-204	Yakima River Fish Screen Plan
2C-205	Yakima River Intake Details
2C-206	Yakima River Intake to Keechelus Portal Profiles
2C-301	Keechelus Portal Site Plan and Section
2C-302	Keechelus Portal Sections and Details
2C-401	I-90 Portal Site Plan
2C-402	I-90 Enlarged Plan
2C-403	I-90 Portal Sections and Details
2C-501	Kachess Reservoir Portal Site Plan
2C-502	Kachess Reservoir Portal Discharge Structure Plan and Profile
2C-503	Kachess Reservoir Portal Discharge Structure Detail

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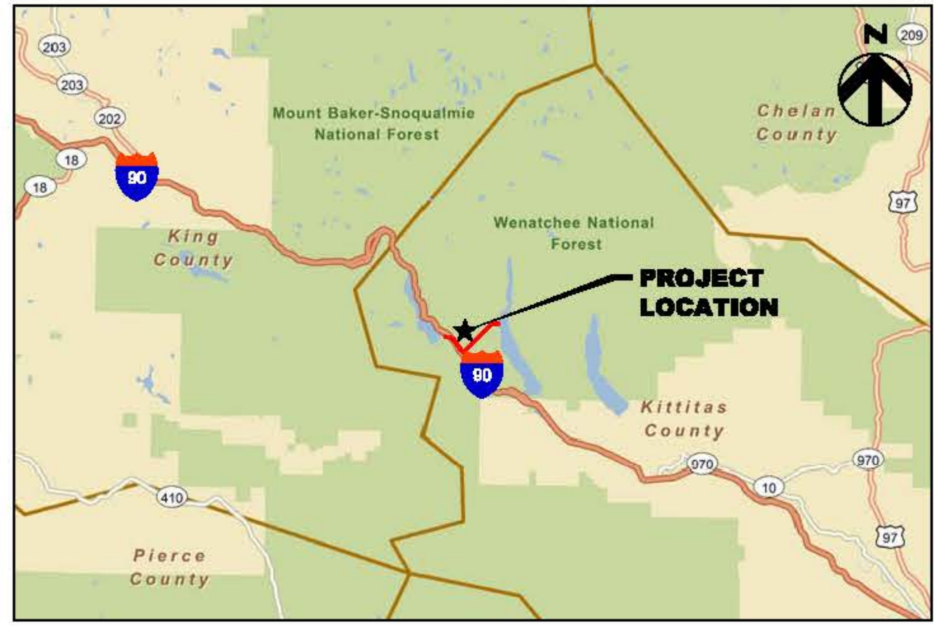
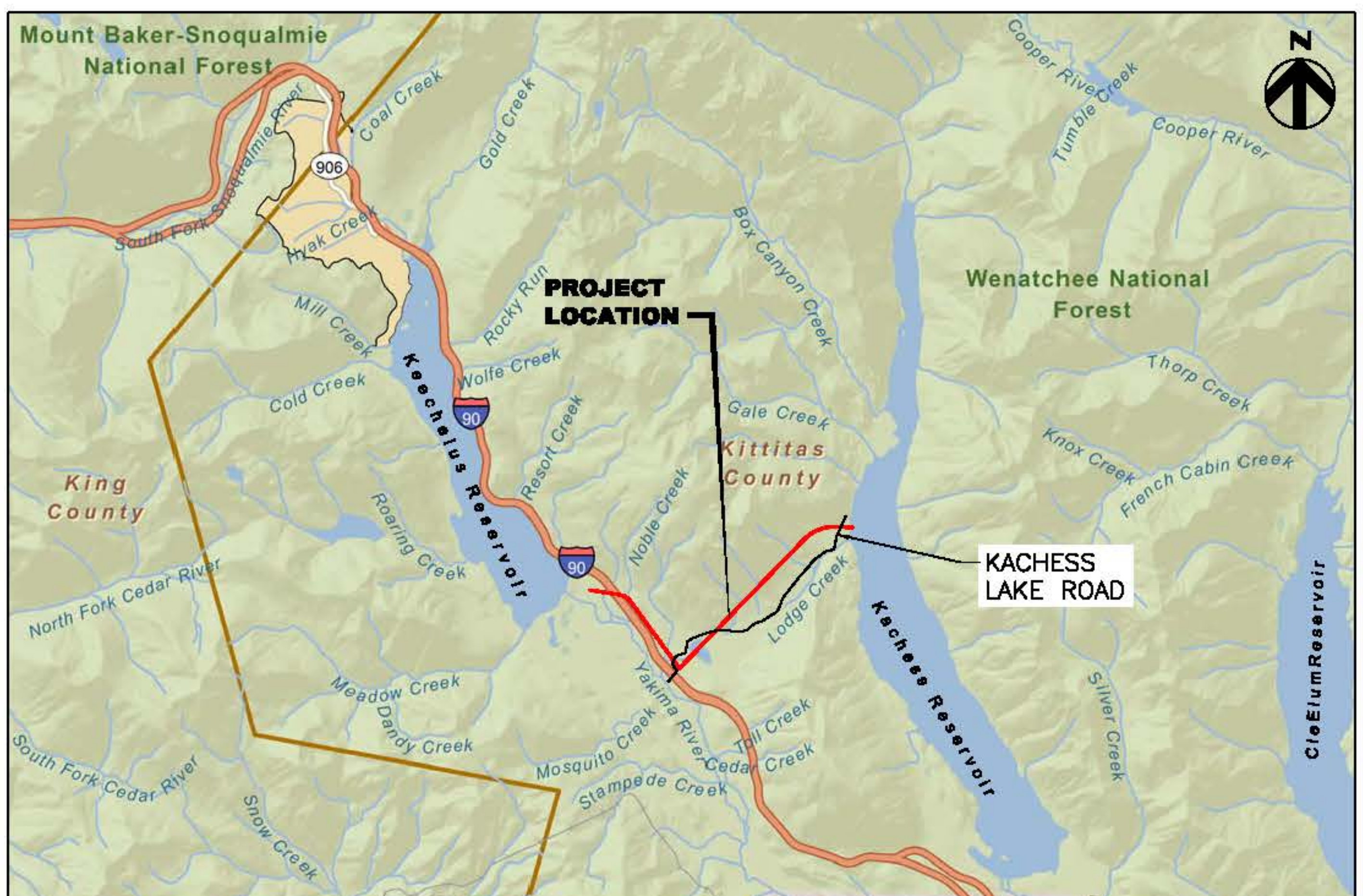
WASHINGTON STATE
SCALE: NTS



VICINITY MAP
SCALE: NTS



LOCATION MAP
SCALE: NTS

INDEX OF DRAWINGS

2G-001	COVER SHEET - LOCATION MAPS AND SHEET INDEX
2C-101	PRESSURE & GRAVITY TUNNEL PLAN AND PROFILE
2C-102	PRESSURE & GRAVITY TUNNEL HYDRAULIC PROFILE
2C-103	PRESSURE & GRAVITY TUNNEL TYPICAL SECTIONS
2C-201	KEECHELUS DIVERSION AREA SITE PLAN
2C-202	YAKIMA RIVER DIVERSION AND INTAKE SITE PLAN
2C-203	YAKIMA RIVER DIVERSION DAM PLAN AND SECTIONS
2C-204	YAKIMA RIVER FISH SCREEN PLAN
2C-205	YAKIMA RIVER INTAKE DETAILS
2C-206	YAKIMA RIVER INTAKE TO KEECHELUS PORTAL PROFILES
2C-301	KEECHELUS PORTAL SITE PLAN AND SECTION
2C-302	KEECHELUS PORTAL SECTIONS AND DETAILS
2C-401	I-90 PORTAL SITE PLAN
2C-402	I-90 PORTAL ENLARGED PLAN
2C-403	I-90 PORTAL SECTION AND DETAILS
2C-501	KACHESS RESERVOIR PORTAL SITE PLAN
2C-502	KACHESS RESERVOIR PORTAL DISCHARGE STRUCTURE PLAN AND PROFILE
2C-503	KACHESS RESERVOIR PORTAL DISCHARGE STRUCTURE DETAIL

Feasibility Design Drawings For

Bureau of Reclamation

Yakima River Basin Integrated Water Resources Management Plan

Keechelus-to-Kachess Conveyance

South Tunnel Alignment

HDR Project No: 224009

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

S. RAJAH
DESIGNED

J. PETERSON
REVIEWED

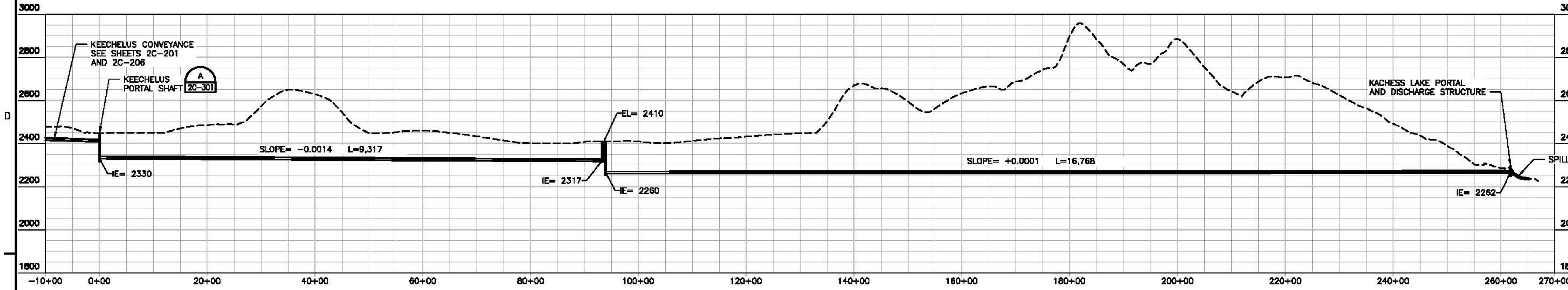
YAKIMA, WA 2014-08-20

COVER SHEET – LOCATION MAPS AND SHEET INDEX

SOUTH TUNNEL ALIGNMENT

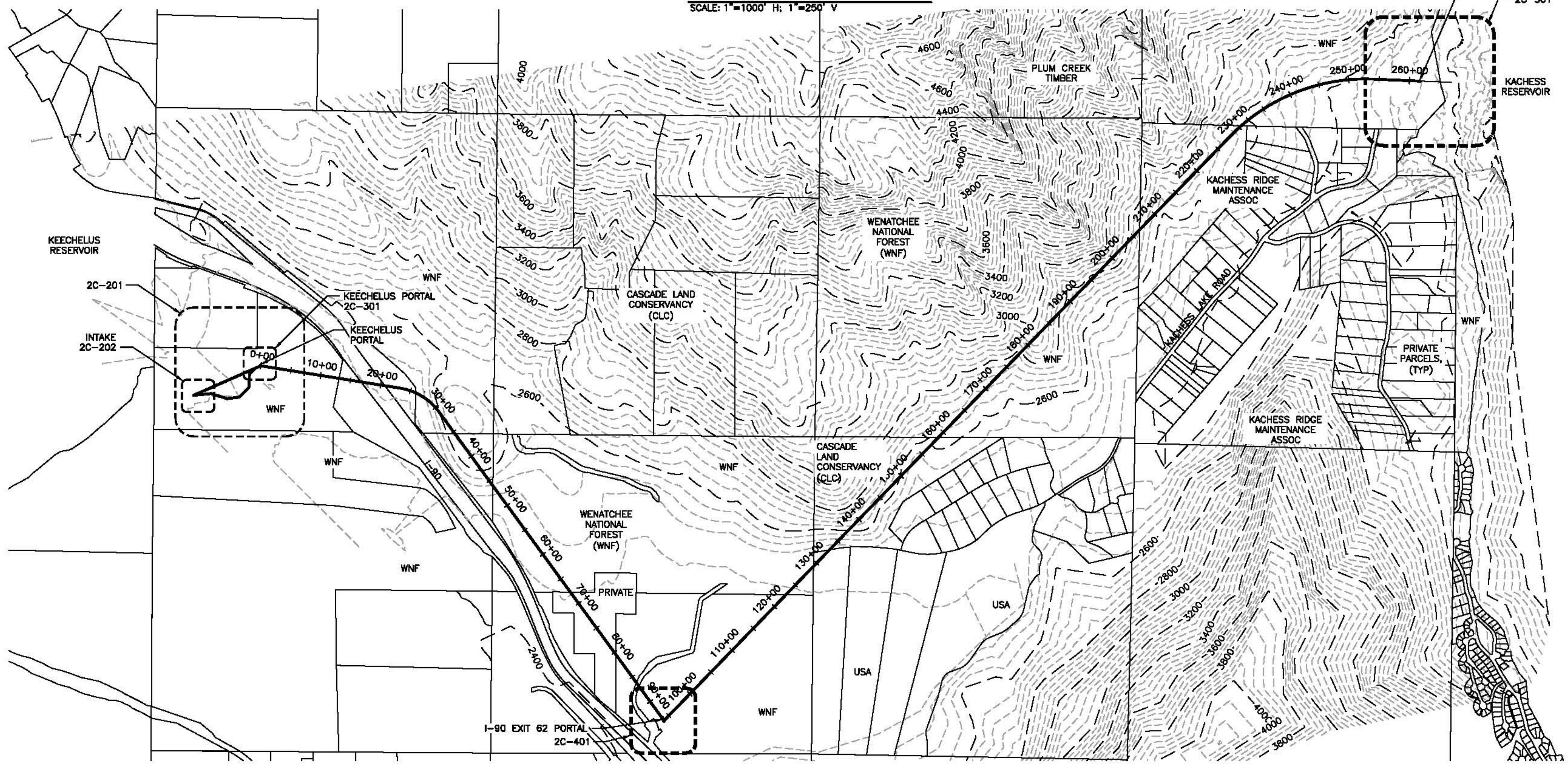
2G-001

SHEET 1 OF 18



PROFILE

SCALE: 1"=1000' H; 1"=250' V



OVERALL SITE PLAN

0 500 1000 2000
SCALE IN FEET

N

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

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DESIGNED J. PETERSON
REVIEWED S. RAJAH
YAKIMA, WA 2014-08-20

PRESSURE & GRAVITY TUNNEL PLAN AND PROFILE

SOUTH TUNNEL ALIGNMENT

2C-101
SHEET 2 OF 18

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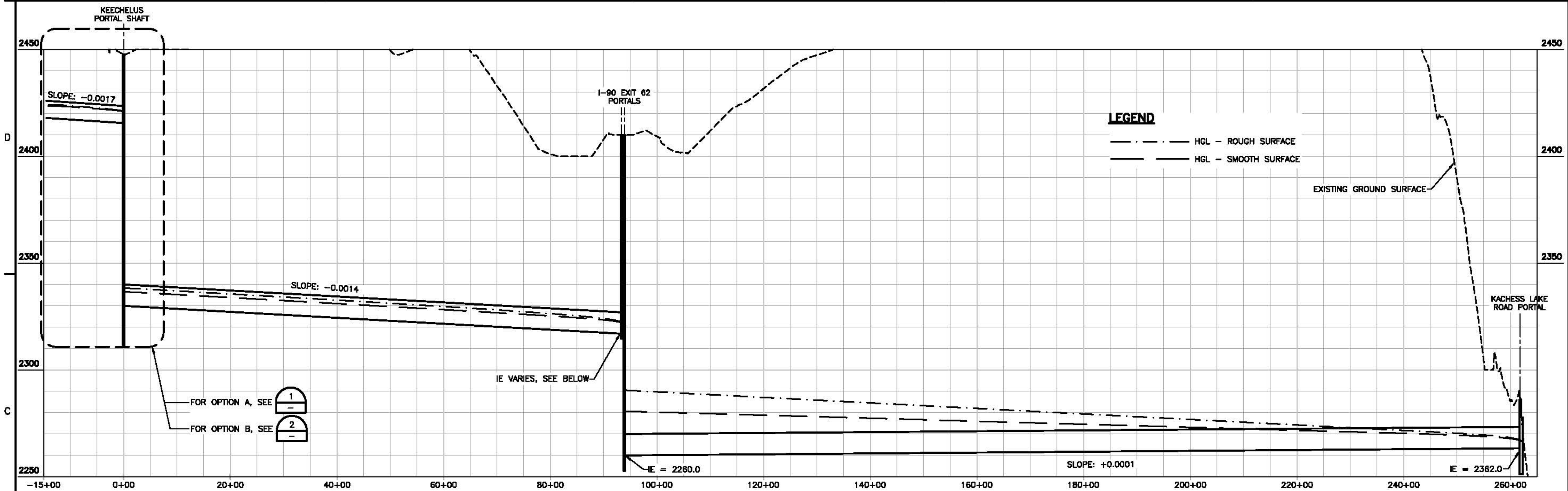
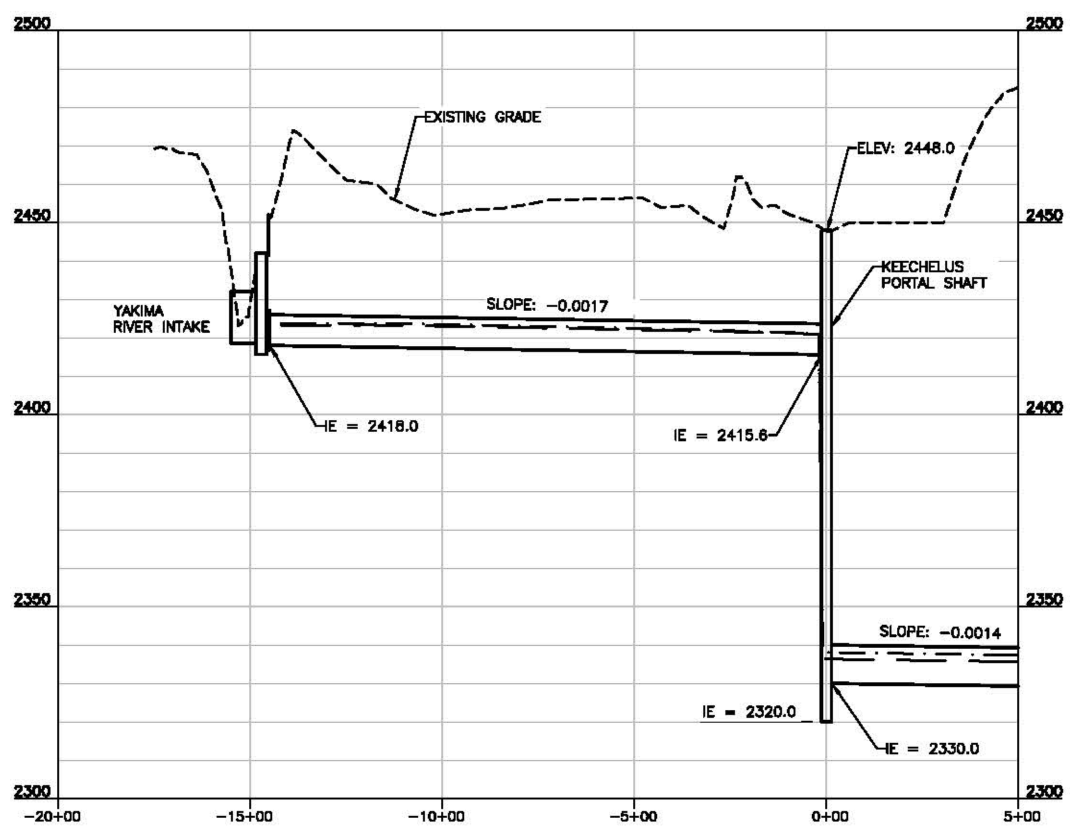
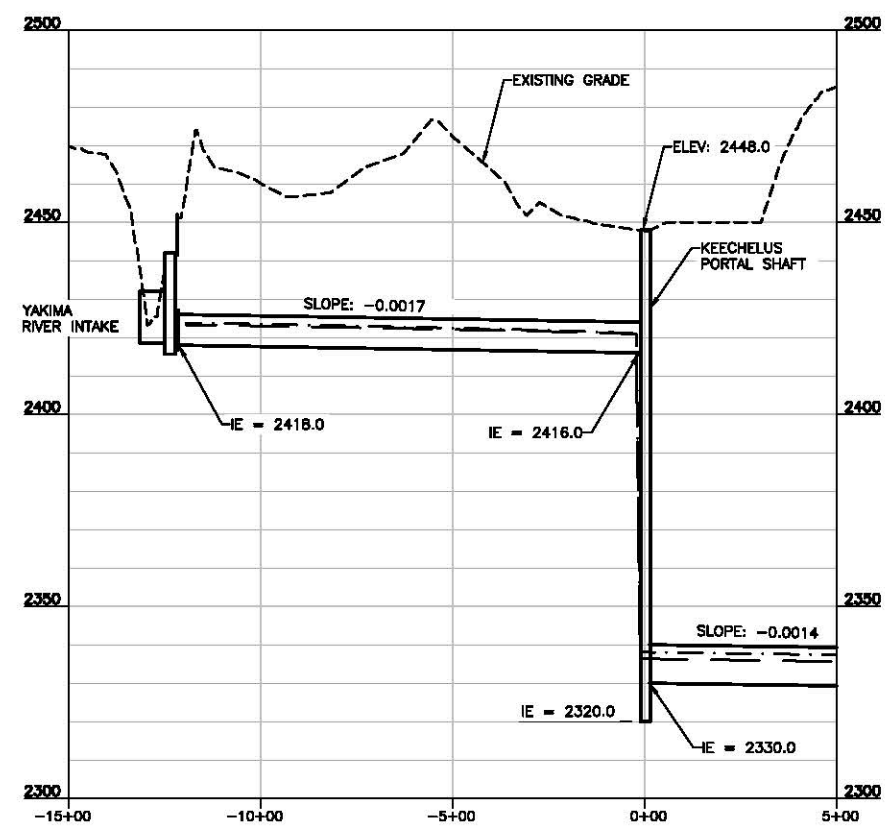


PROFILE
SCALE: 1"=1000' H; 1"=25' V



PROFILE - OPTION A PIPELINE 1
SCALE: 1"=250' H; 1"=25' V



PROFILE - OPTION B PIPELINE 2
SCALE: 1"=250' H; 1"=25' V

HYDRAULIC DESIGN PARAMETERS

- DESIGN FLOW RATE: 400 CFS
- FISH LADDER FLOW: 20 CFS
- HYDRAULIC REQUIREMENTS:
  - GRAVITY FLOW WITH MIN FREEBOARD 0.18 TIMES INSIDE DIAMETER AND NOT LESS THAN 1.5 FEET.
  - MAX DESIGN FLOW VELOCITY: LESS THAN 20 FT/SEC (PREFERABLY LESS THAN 10 FT/SEC); FOR CONCRETE LINED TUNNELS LESS THAN 10 FT/SEC; FOR UNLINED TUNNELS LESS THAN 5 FT/SEC.
- RUGOSITY OF LINING OR INTERIOR SURFACE:
  - PIPELINES: 0.001 FT (ROUGH); 0.0002 FT (SMOOTH)
  - UNLINED BORED TUNNELS: 0.059 FT (ROUGH); 0.0061 FT (SMOOTH)
  - CONCRETE LINED BORED TUNNELS: 0.002 FT (ROUGH); 0.0003 FT (SMOOTH)
- FROUDE NUMBER: LESS THAN 0.7 (EXCEPT NEAR PLANNED FLOW DISCONTINUITIES AND DROPS)
- STANDARDS:
  - UNITED STATES BUREAU OF RECLAMATION (USBR). (1994). "DESIGN STANDARDS NO. 3 - WATER CONVEYANCE SYSTEMS", DS-3, SEPTEMBER 30.
- DESIGN CRITERIA:
  - HDR ENGINEERING, INC. (2014). "TECHNICAL MEMORANDUM: KEECHELUS-TO-KACHESS CONVEYANCE DESIGN CRITERIA, YAKIMA RIVER BASIN INTEGRATED WATER RESOURCE MANAGEMENT PLAN", PREPARED FOR U.S. BUREAU OF RECLAMATION, CONTRACT NO. 08CA10677A ID/IQ, JUNE (DRAFT).
- VERTICAL DATUM:
  - NAVD 88
  - ELEVATIONS ARE APPROXIMATE

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

PRESSURE & GRAVITY TUNNEL HYDRAULIC PROFILE

SOUTH TUNNEL ALIGNMENT

2C-102
SHEET 3 OF 18

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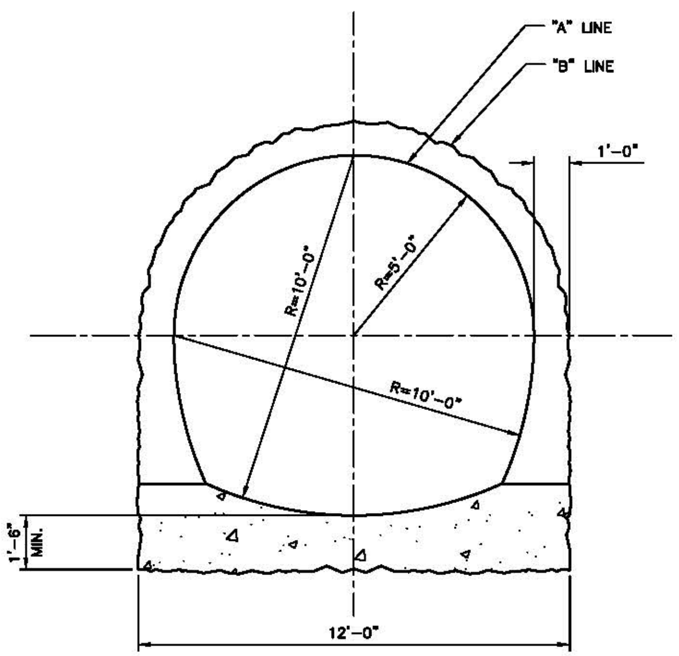
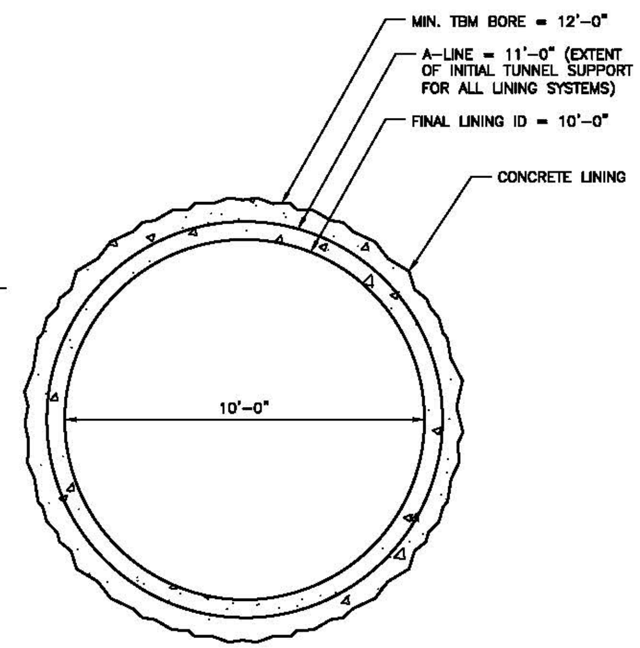
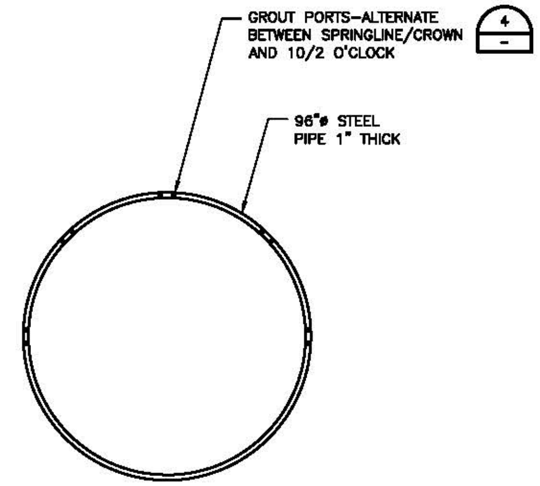


NOTE:
1. REINFORCEMENT NOT SHOWN.

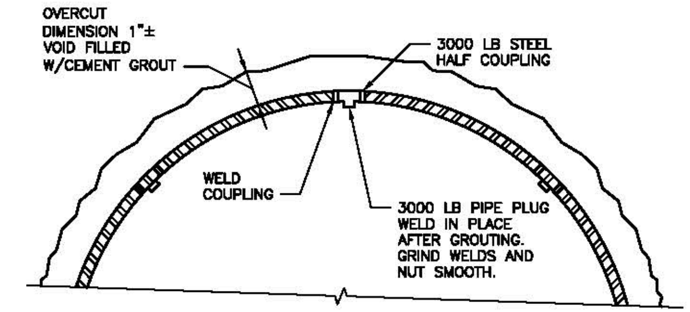
HORSESHOE TUNNEL SECTION 1 –
SCALE: 3/8" = 1'-0"



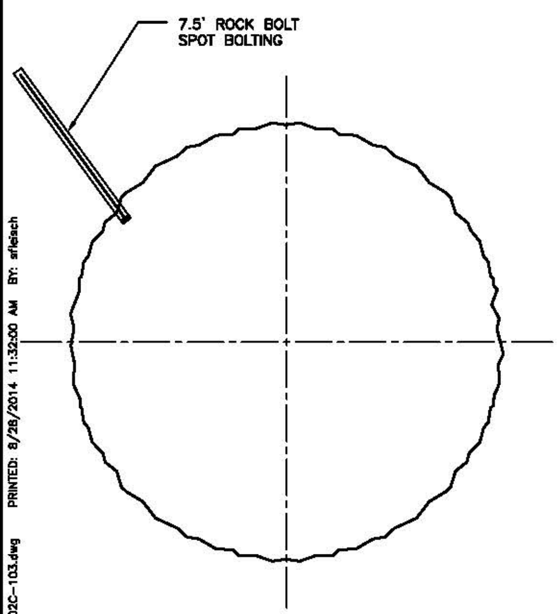
TBM TUNNEL SECTION 2 2C-101
SCALE: 3/8" = 1'-0"



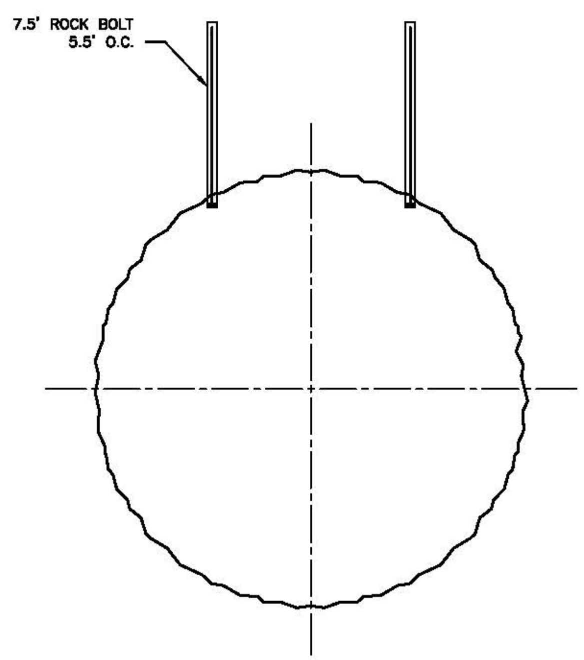
JACKED TUNNEL SECTION 3 2C-201
SCALE: 3/8" = 1'-0"



GROUT PORT DETAIL 4 –
SCALE: NTS



CLASS I SUPPORT TBM TUNNEL SECTION 5 2C-101
SCALE: 3/8" = 1'-0"



CLASS II SUPPORT TBM TUNNEL SECTION 6 2C-101
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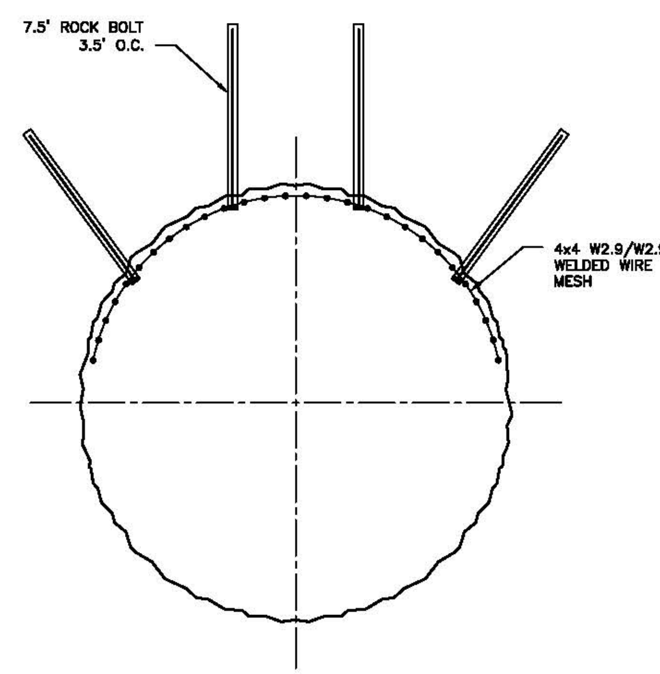
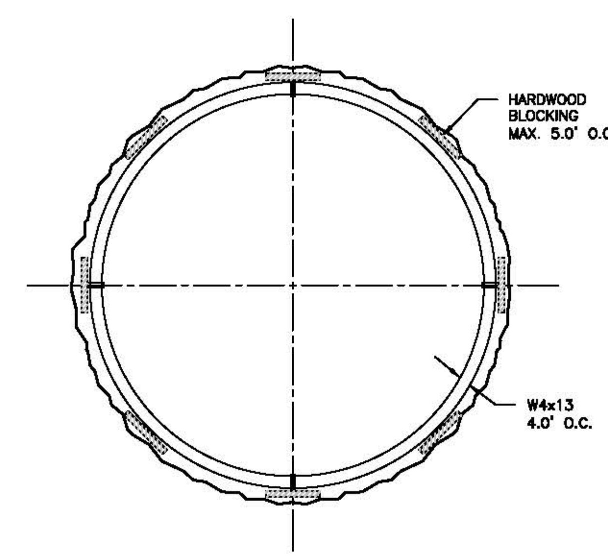


CLASS III SUPPORT TBM TUNNEL SECTION 7 2C-101
SCALE: 3/8" = 1'-0"



CLASS IV SUPPORT TBM TUNNEL SECTION 8 2C-101
SCALE: 3/8" = 1'-0"

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. BALLAGEER
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

PRESSURE & GRAVITY TUNNEL TYPICAL SECTIONS

SOUTH TUNNEL ALIGNMENT

2C-103
SHEET 4 OF 18

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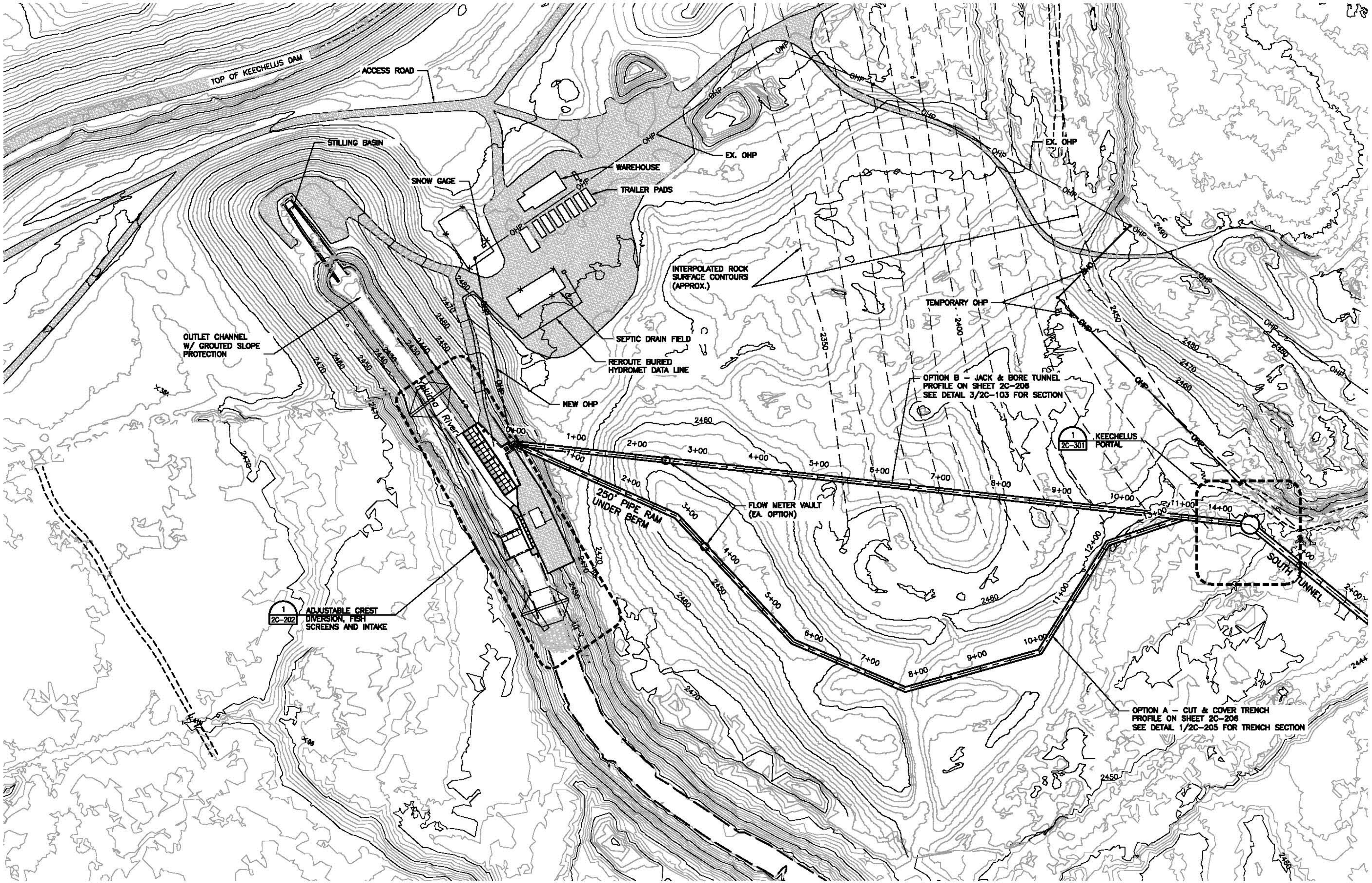

NOTE:

1. CONTOURS ARE BASED ON TWO FILES DATED 2000 AND 2007. DISCREPANCIES IN DATUM HAVE BEEN NOTED AND REQUIRE RESOLUTION BY A SURVEYOR.

SITE PLAN

0 40 80 160

SCALE IN FEET

N

0 1" 2"

FEASIBILITY DRAWING

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KEECHELUS RESERVOIR TO KACHESS RESERVOIR

K. GOSS
DESIGNED

J. PETERSON
REVIEWED

YAKIMA, WA 2014-08-20

KEECHELUS DIVERSION AREA SITE PLAN

SOUTH TUNNEL ALIGNMENT

2C-201

SHEET 5 OF 18

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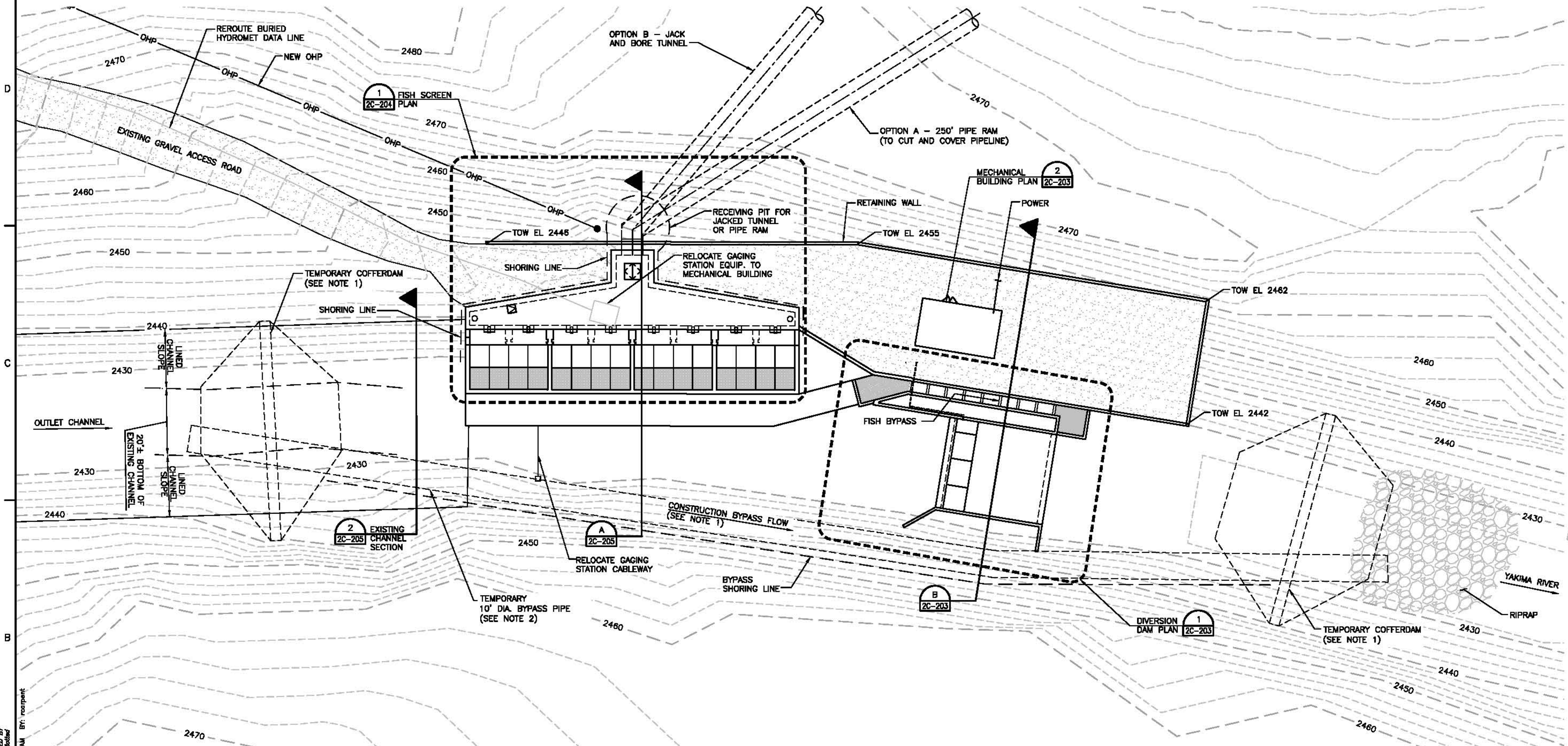

DESIGN CRITERIA

- MAXIMUM DIVERSION: 400 CFS
- MINIMUM POOL DEPTH: 7.0 FT
- SCREEN AREA: 1,150 SQ FT (4 BAYS, 29.25 FT LONG x 9.92 FT WIDE EACH)
- MAXIMUM APPROACH VELOCITY: 0.40 FPS
- MINIMUM 0.8 FPS SWEEPING FLOW
- AUTOMATED AIR BURST CLEANING

DIVERSION & INTAKE SITE PLAN 1 –

0 10 20 40
SCALE IN FEET

N

NOTES:

1. COFFERDAM AND RIVER BYPASS TO BE IMPLEMENTED BY CONTRACTOR. PIPE BYPASS IS ONE ALTERNATIVE. RELOCATION WILL BE REQUIRED DURING CONSTRUCTION TO ACCOMMODATE COMPLETION OF ADJUSTABLE CREST DIVERSION DAM AND SCREEN STRUCTURE.
2. BYPASS PIPE ALIGNMENT IS APPROXIMATE.

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

DATE AND TIME PLOTTED Not Plotted
PLOTTED BY Not Plotted
PRINTED: 1/14/2015 10:53:58 AM BY: rcorpent
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HDR

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YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

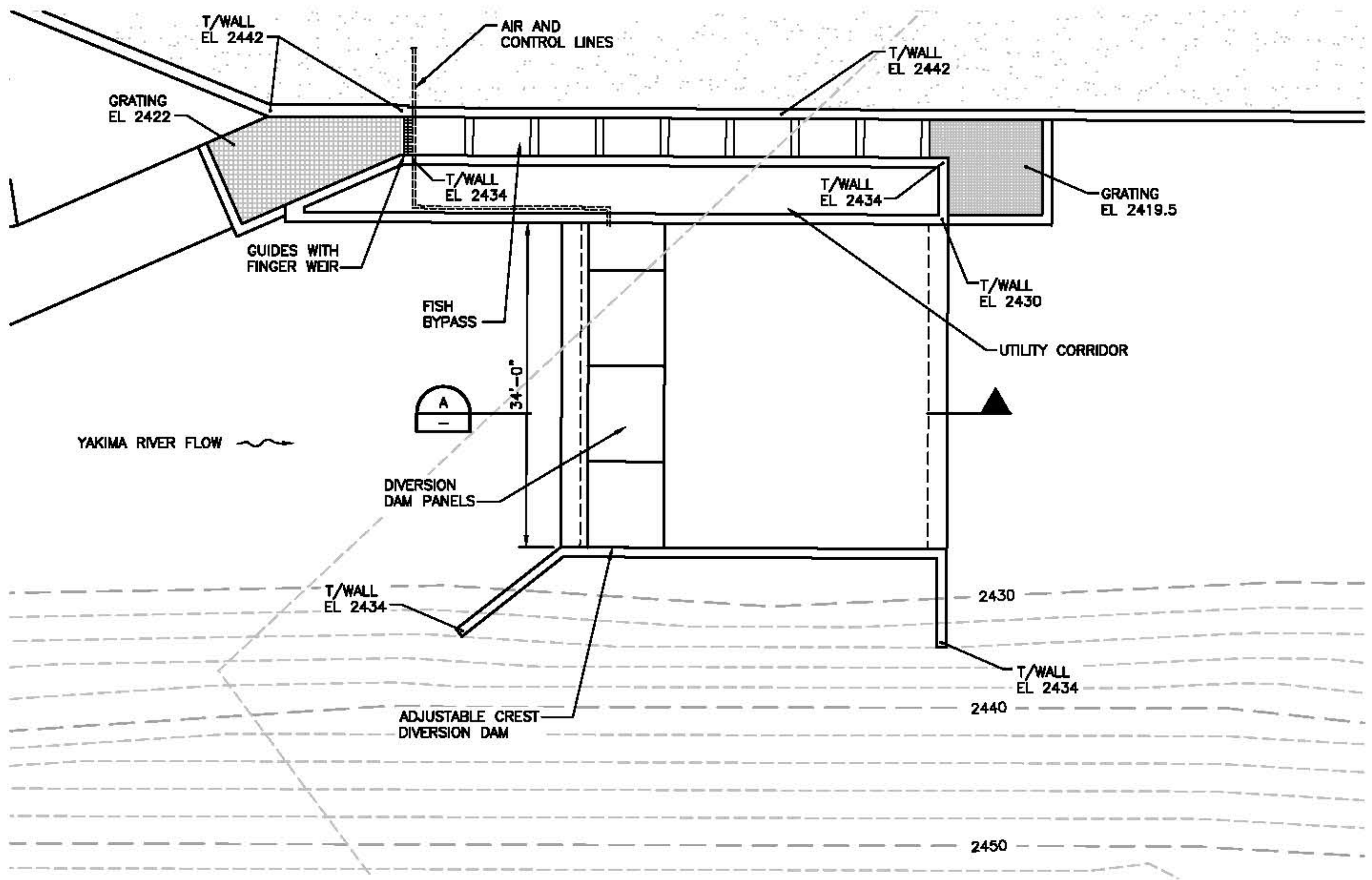
DESIGNED J. NELSON
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER DIVERSION AND INTAKE SITE PLAN

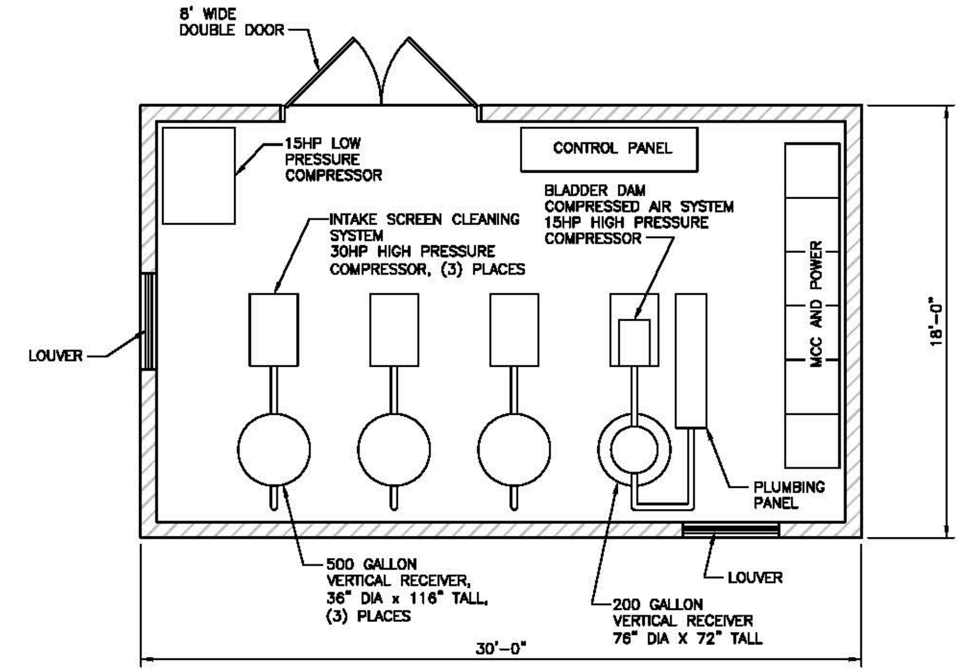
SOUTH TUNNEL ALIGNMENT

0 1" 2"

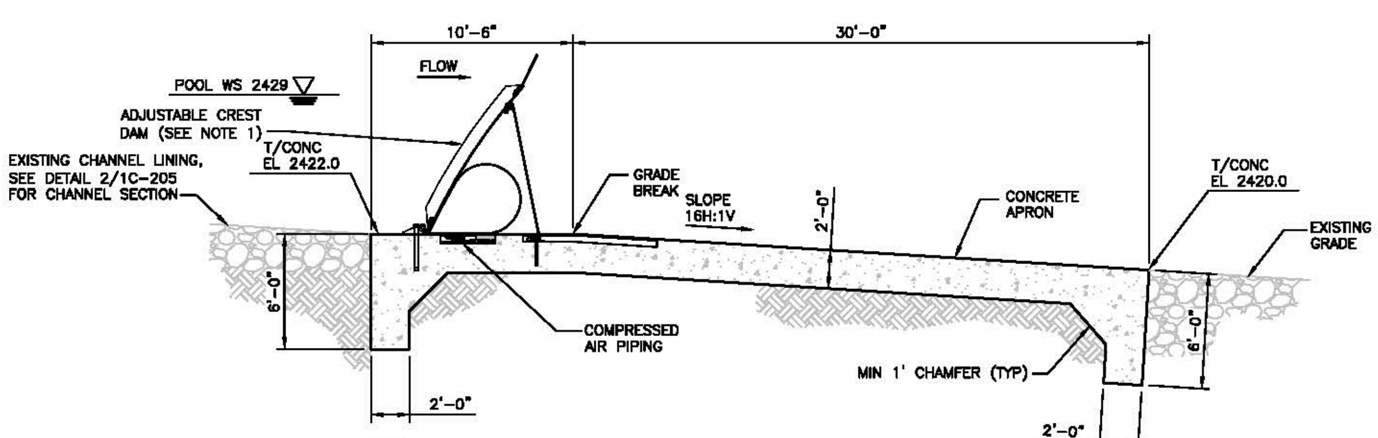
2C–202
SHEET 6 OF 18



DIVERSION DAM PLAN 1 2C-202
SCALE: 1"=10'

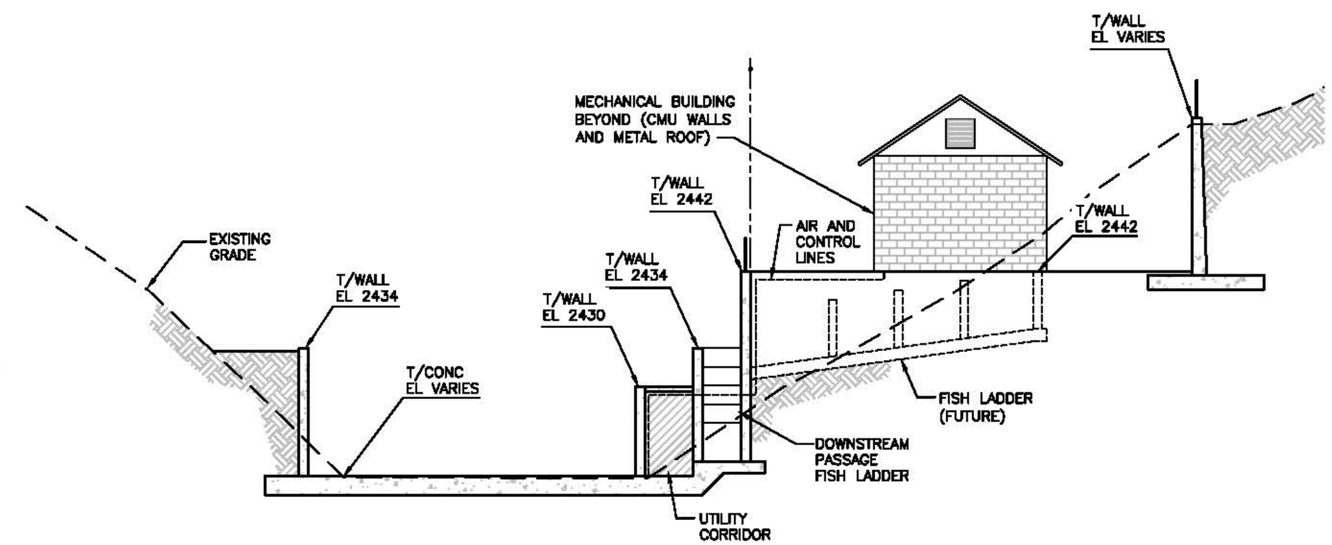


MECHANICAL BUILDING PLAN 2 2C-202
SCALE: 1/4"=1'-0"



NOTE:
1. INFLATABLE DAM SHOWN, BUT ANOTHER ADJUSTABLE DAM TYPE COULD BE USED.

DIVERSION DAM SECTION A —
SCALE: 1"=5'



DAM SECTION B 2C-202
SCALE: 1"=10'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

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YAKIMA RIVER DIVERSION DAM PLAN AND SECTION

SOUTH TUNNEL ALIGNMENT

2C-203
SHEET 7 OF 18

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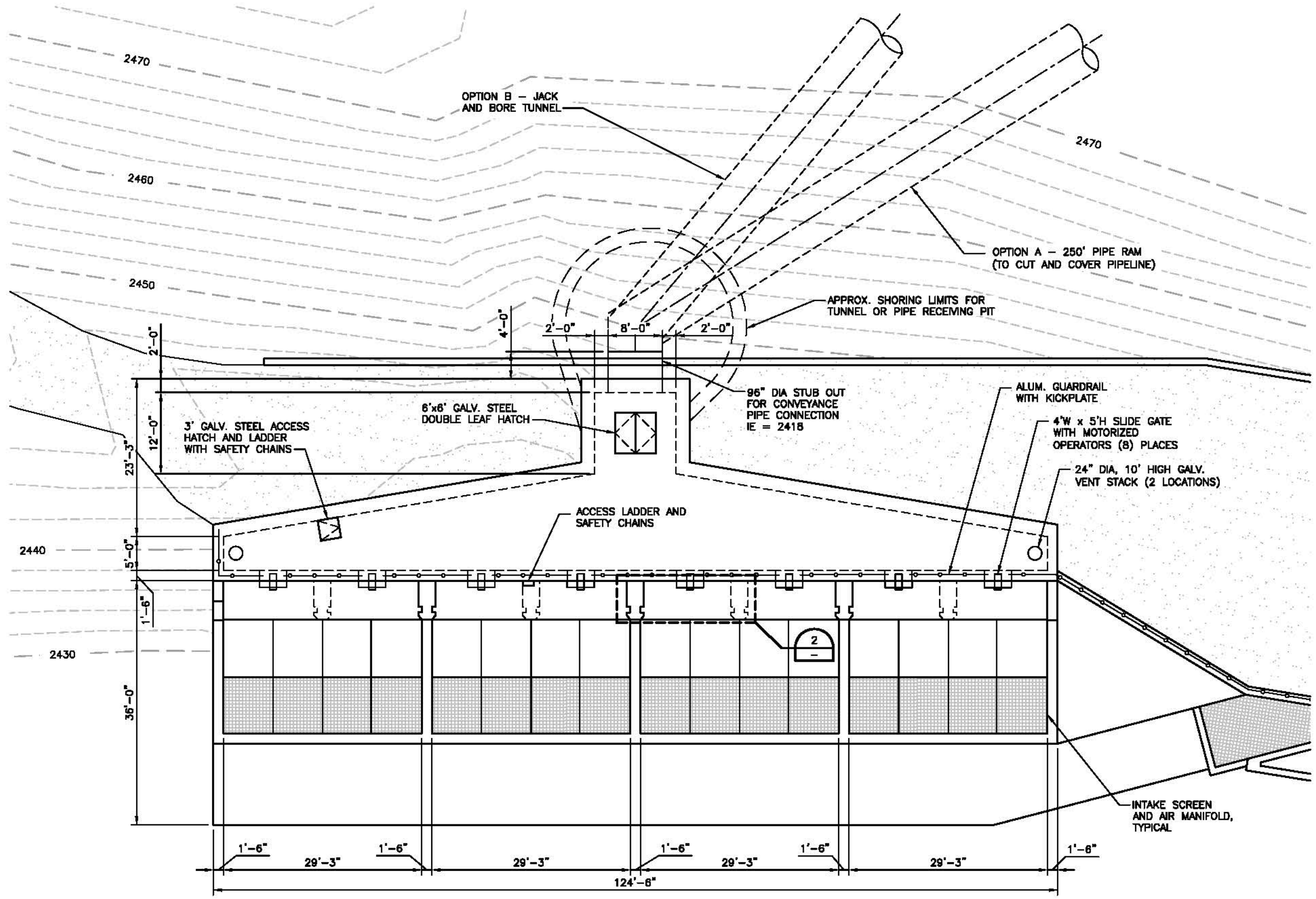
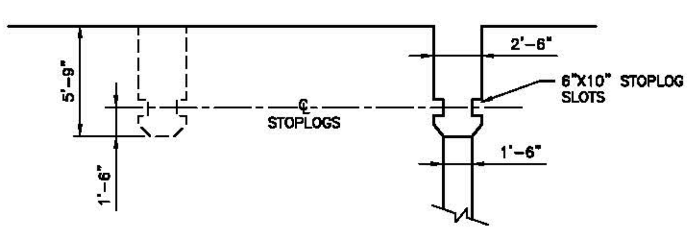


FISH SCREEN PLAN 1

0 5 10 20
SCALE IN FEET



FISH SCREEN PLAN 2
SCALE: 1" = 5'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED: J. NELSON
REVIEWED: J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER DIVERSION FISH SCREEN PLAN

SOUTH TUNNEL ALIGNMENT

2C-204
SHEET 8 OF 18

DATE AND TIME PLOTTED: Not Plotted
PLOTTED BY: Not Plotted
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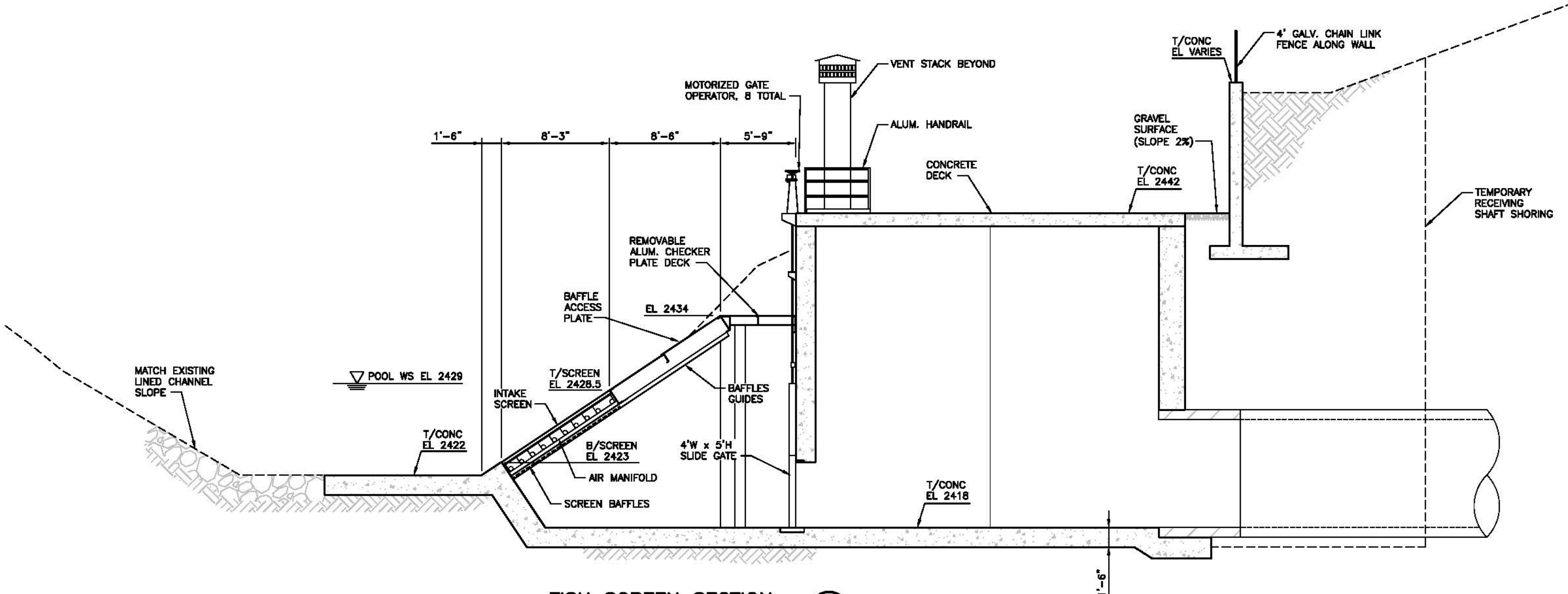
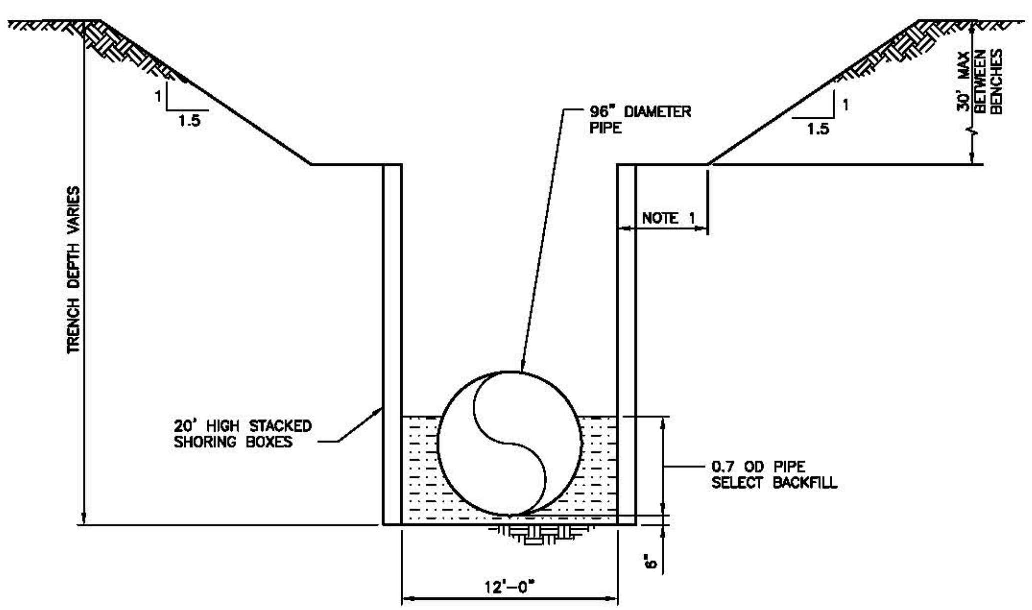


FISH SCREEN SECTION (A / 2C-202)

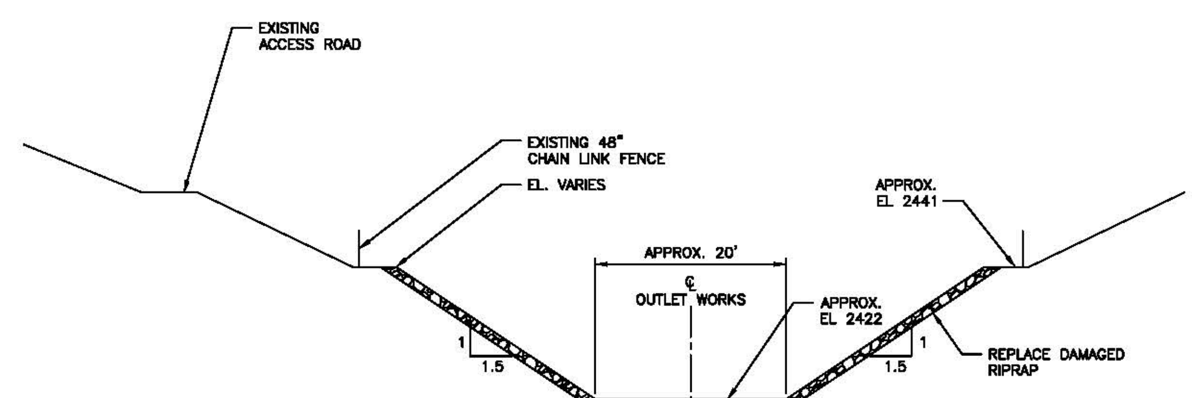
SCALE: 1"=5'



NOTE:
1. BENCH WIDTH AND CUT SLOPE TO BE DETERMINED BY GEOTECH.

OPTION A TRENCH SECTION – YAKIMA RIVER INTAKE TO KEECHELUS PORTAL (1 / VARIES)

SCALE: 3/16"=1'-0"



NOTE:
1. EXISTING CHANNEL SECTION IS BASED ON SECTION C–C FROM DRAWING 32–D–622, KEECHELUS DAM, OUTLET WORKS REHABILITATION, MARCH 17, 1976.

EXISTING CHANNEL SECTION (2 / 2C-202)

SCALE: NTS

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. NELSON

REVIEWED J. PETERSON

YAKIMA, WA 2014–08–20

YAKIMA RIVER DIVERSION INTAKE DETAILS

SOUTH TUNNEL ALIGNMENT

2C–205

SHEET 9 OF 18

DATE AND TIME PLOTTED Not Plotted
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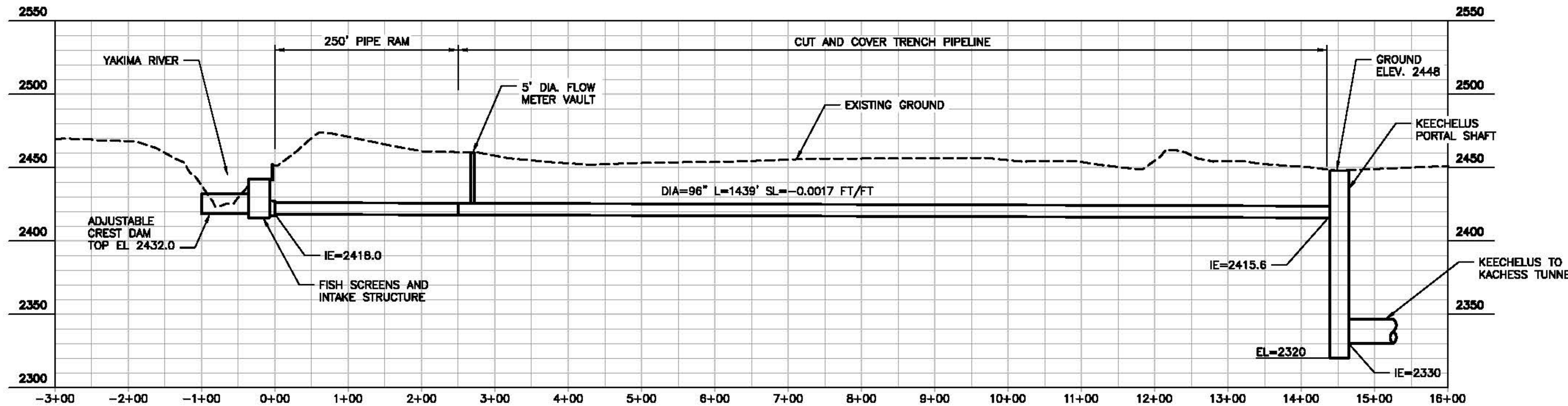
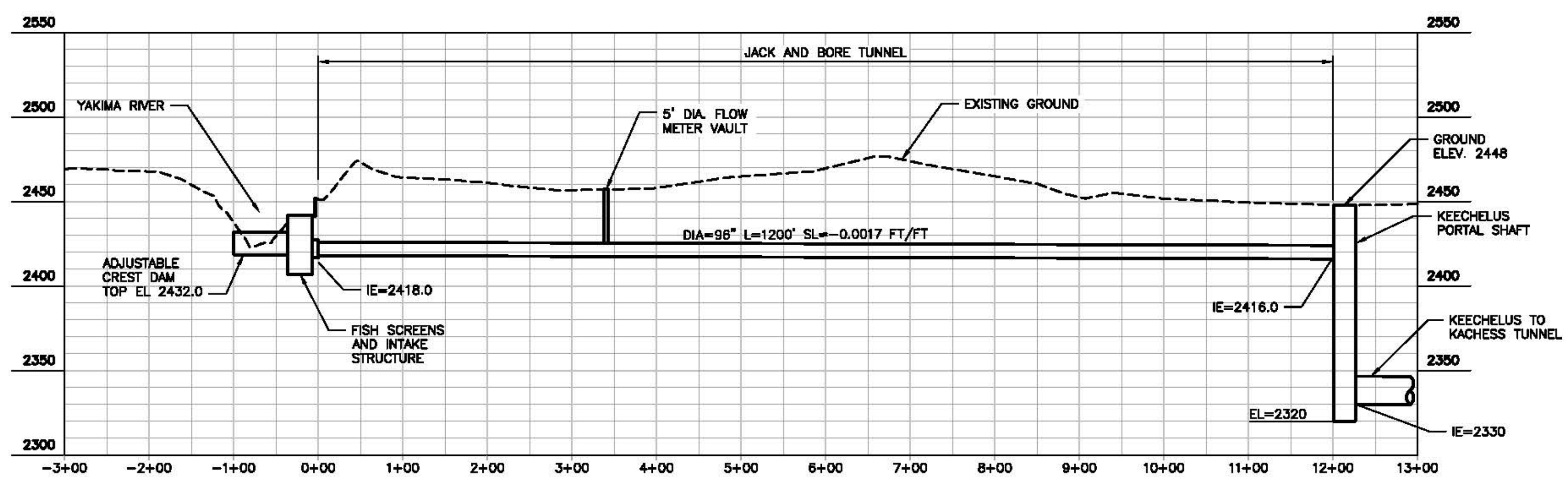


CUT & COVER TRENCH PIPELINE PROFILE – OPTION A

SCALE: 1"=100' H, 1"=50' V



TUNNEL PIPELINE PROFILE – OPTION B

SCALE: 1"=100' H, 1"=50' V

0 1" 2"

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED K. GOSS

REVIEWED J. PETERSON

YAKIMA, WA 2014-08-20

YAKIMA RIVER INTAKE TO KEECHELUS PORTAL PROFILES

SOUTH TUNNEL ALIGNMENT

2C-206

SHEET 10 OF 18

CAD SYSTEM AUTOCAD
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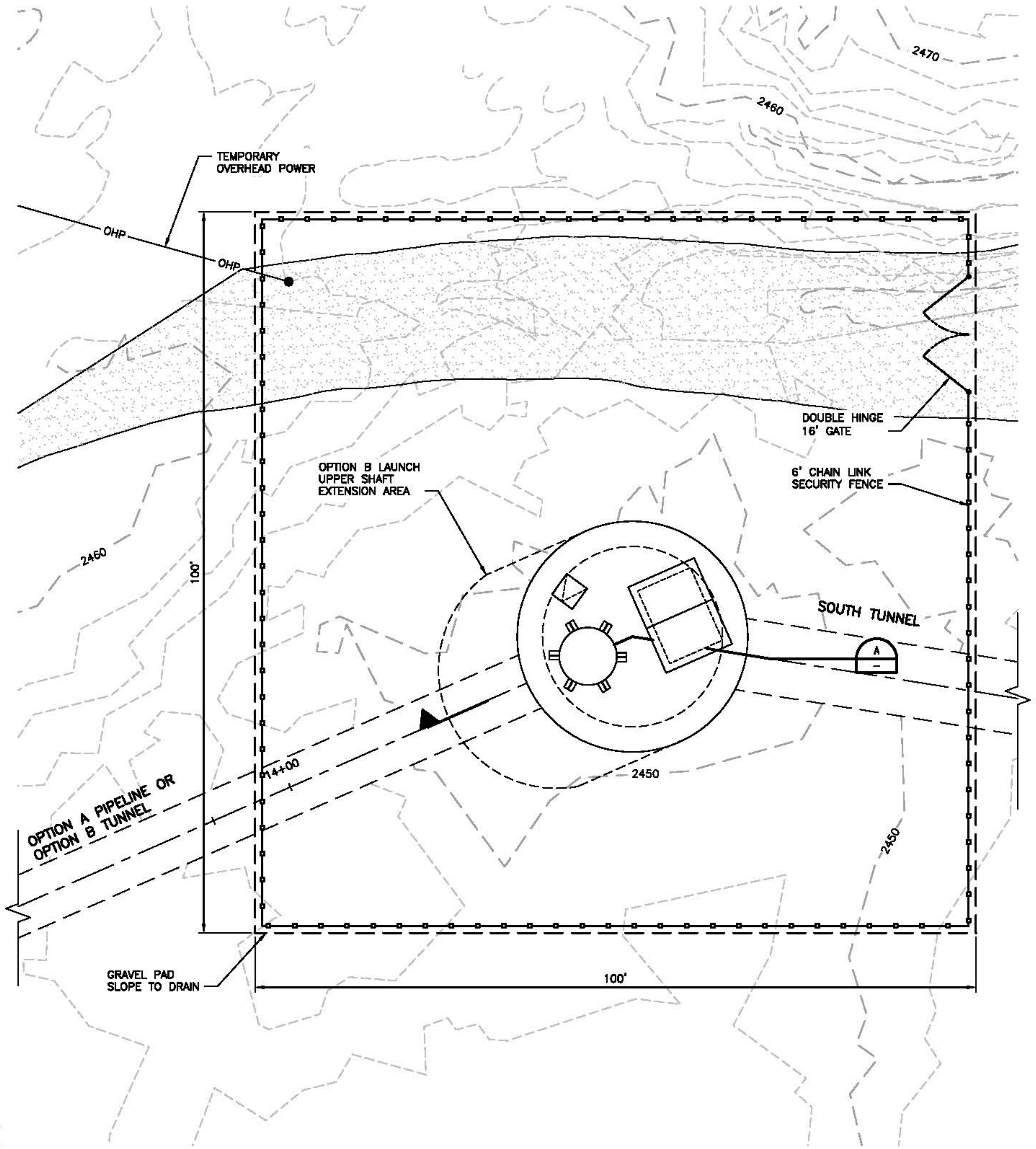
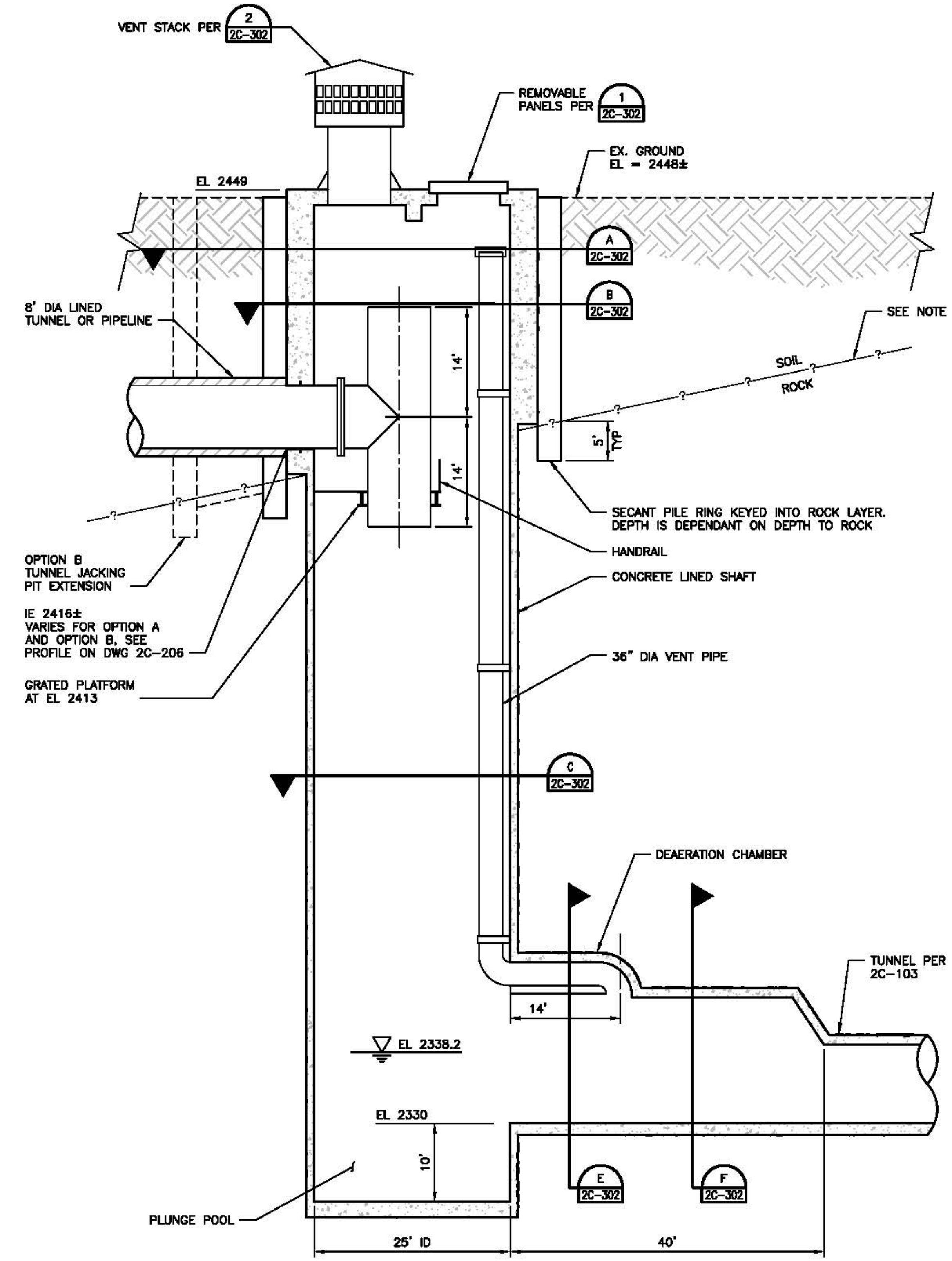


SITE PLAN 1 2C-201

0 5 10 20 SCALE IN FEET

N



NOTE:
1. ASSUMED ROCK CONTACT BASED ON LIMITED SUBSURFACE DATA.

KEECHELUS PORTAL SECTION A
SCALE: 1"=10'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

KEECHELUS PORTAL SITE PLAN AND SECTION

SOUTH TUNNEL ALIGNMENT

2C-301
SHEET 11 OF 18

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PLOTTED BY Not Plotted
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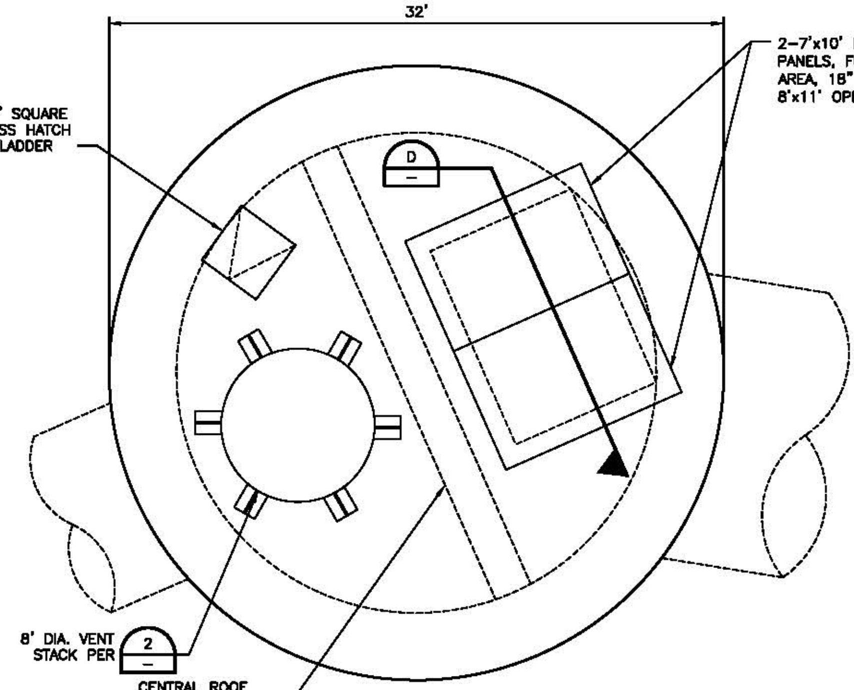
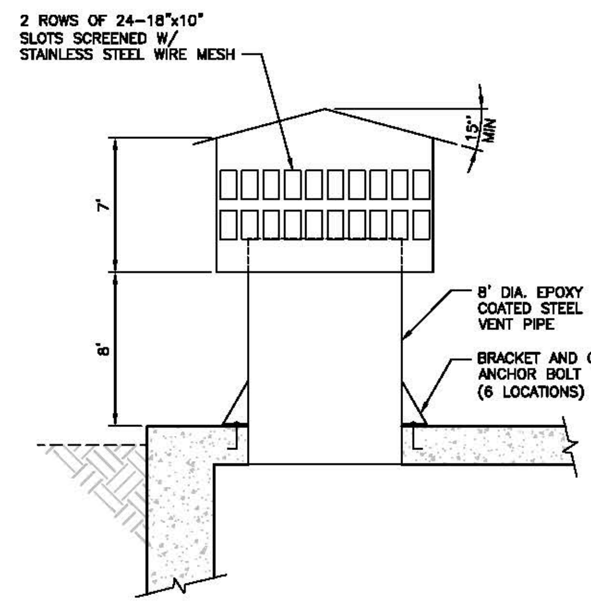
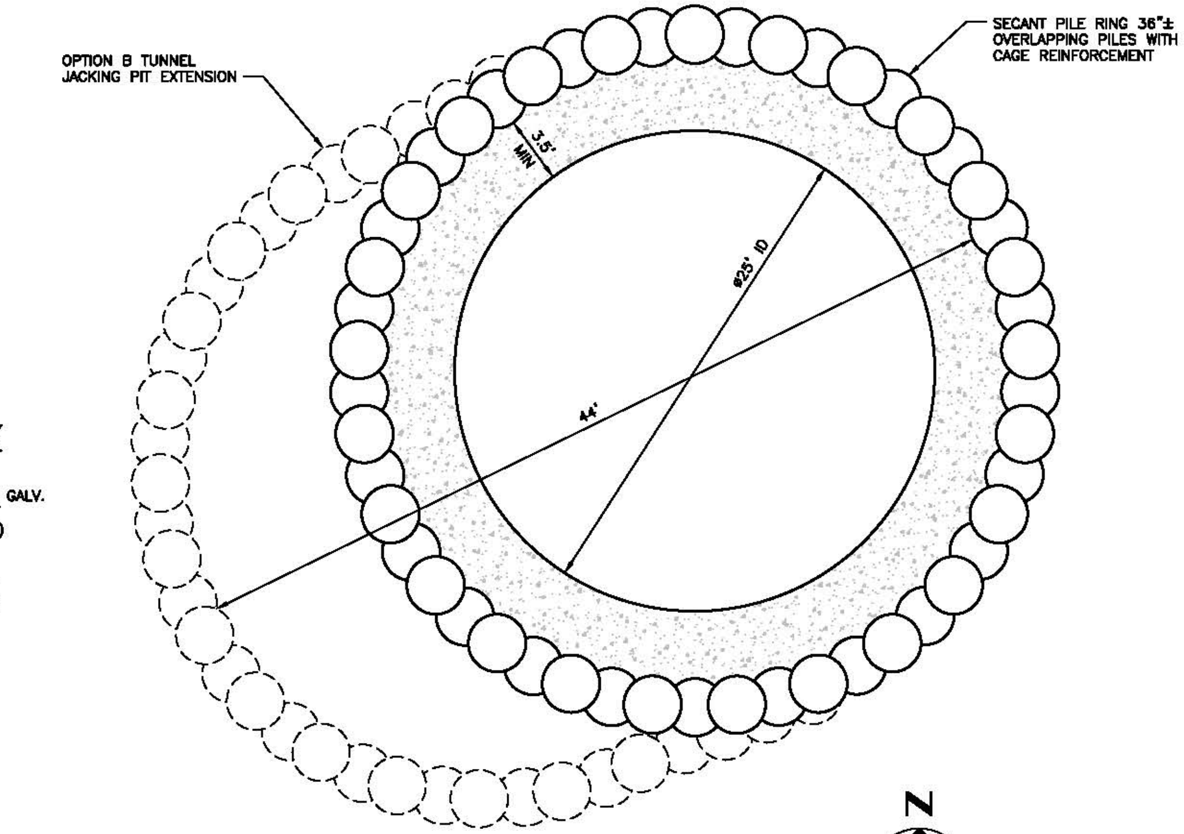


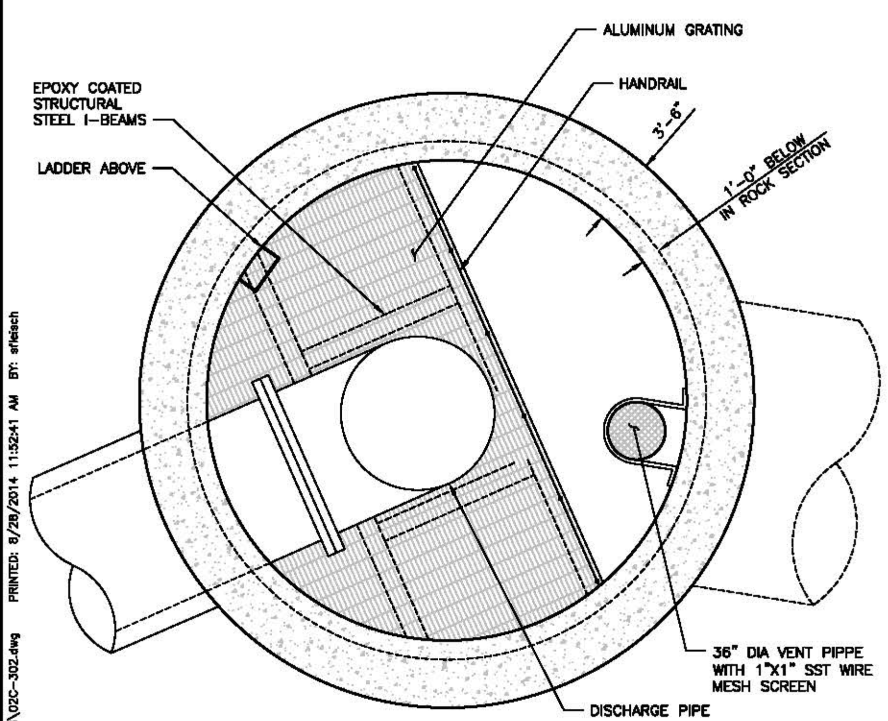
PORTAL SHAFT TOP SLAB PLAN
SCALE: 1"=5'



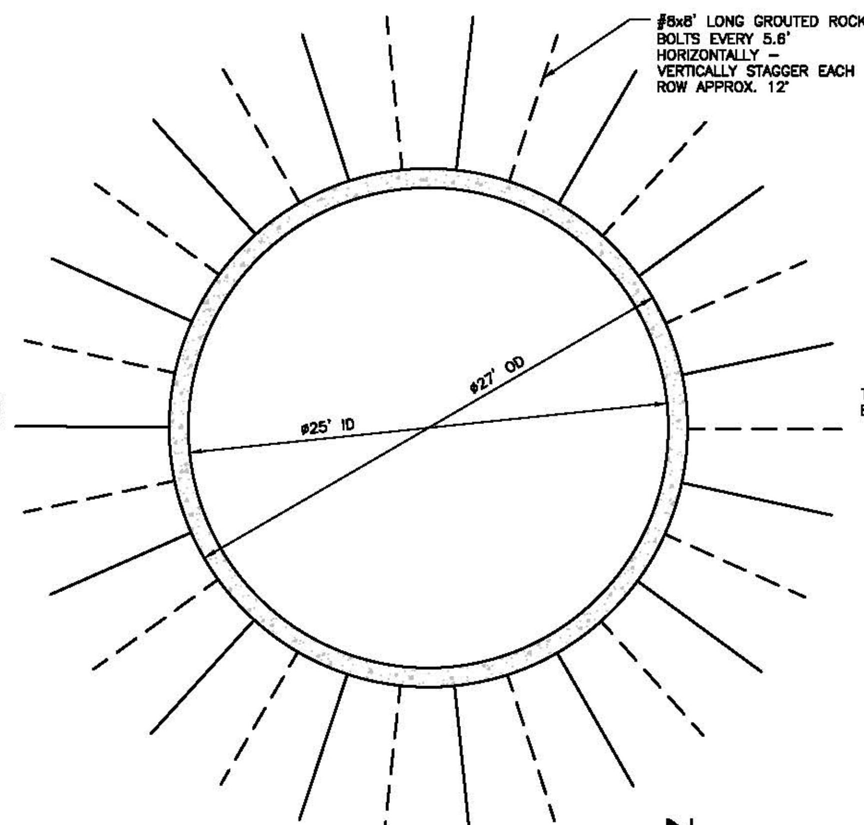
VENT STACK DETAIL
SCALE: 1"=5'



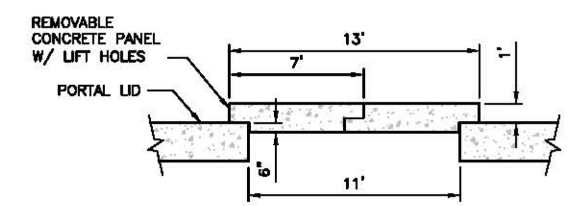
SOFT GROUND EXCAVATION SECTION
SCALE: 1"=5'
A 2C-301



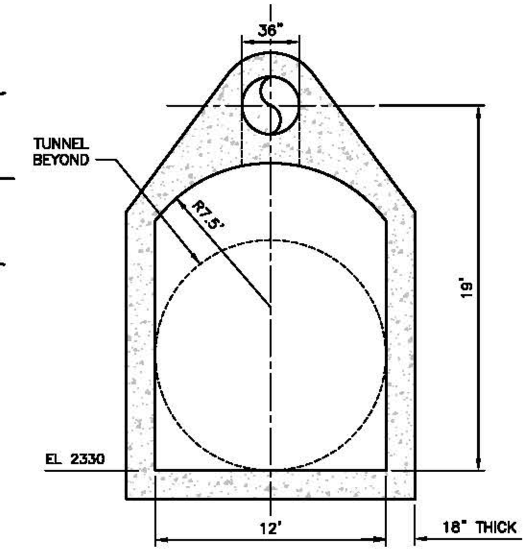
ELEVATION 2413 PLATFORM SECTION
SCALE: 1"=5'
B 2C-301



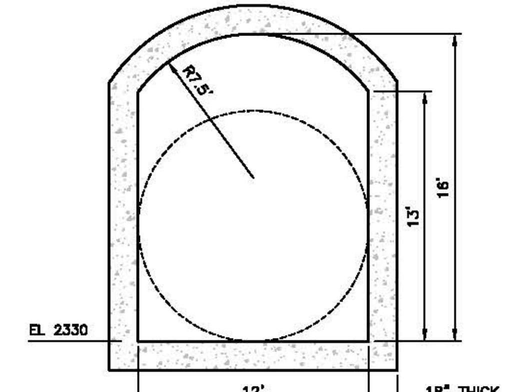
ROCK EXCAVATION SECTION
SCALE: 1"=5'
C 2C-301



REMOVABLE PANEL DETAIL
SCALE: 1"=5'



DEAERATION CHAMBER SECTION
SCALE: 1"=5'
E 2C-301



DEAERATION CHAMBER SECTION
SCALE: 1"=5'
F 2C-301

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

JAMES C. PETERSON, STATE OF WASHINGTON, 27574, REGISTERED PROFESSIONAL ENGINEER

KANDIAH SRIBALASKANDARAJAH, STATE OF WASHINGTON, 34049, REGISTERED PROFESSIONAL ENGINEER

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YAKIMA PROJECT - WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED	S. RAJAH
REVIEWED	J. PETERSON
YAKIMA, WA	2014-08-20

KEECHELUS PORTAL SECTIONS AND DETAILS

SOUTH TUNNEL ALIGNMENT

2C-302
SHEET 12 OF 18

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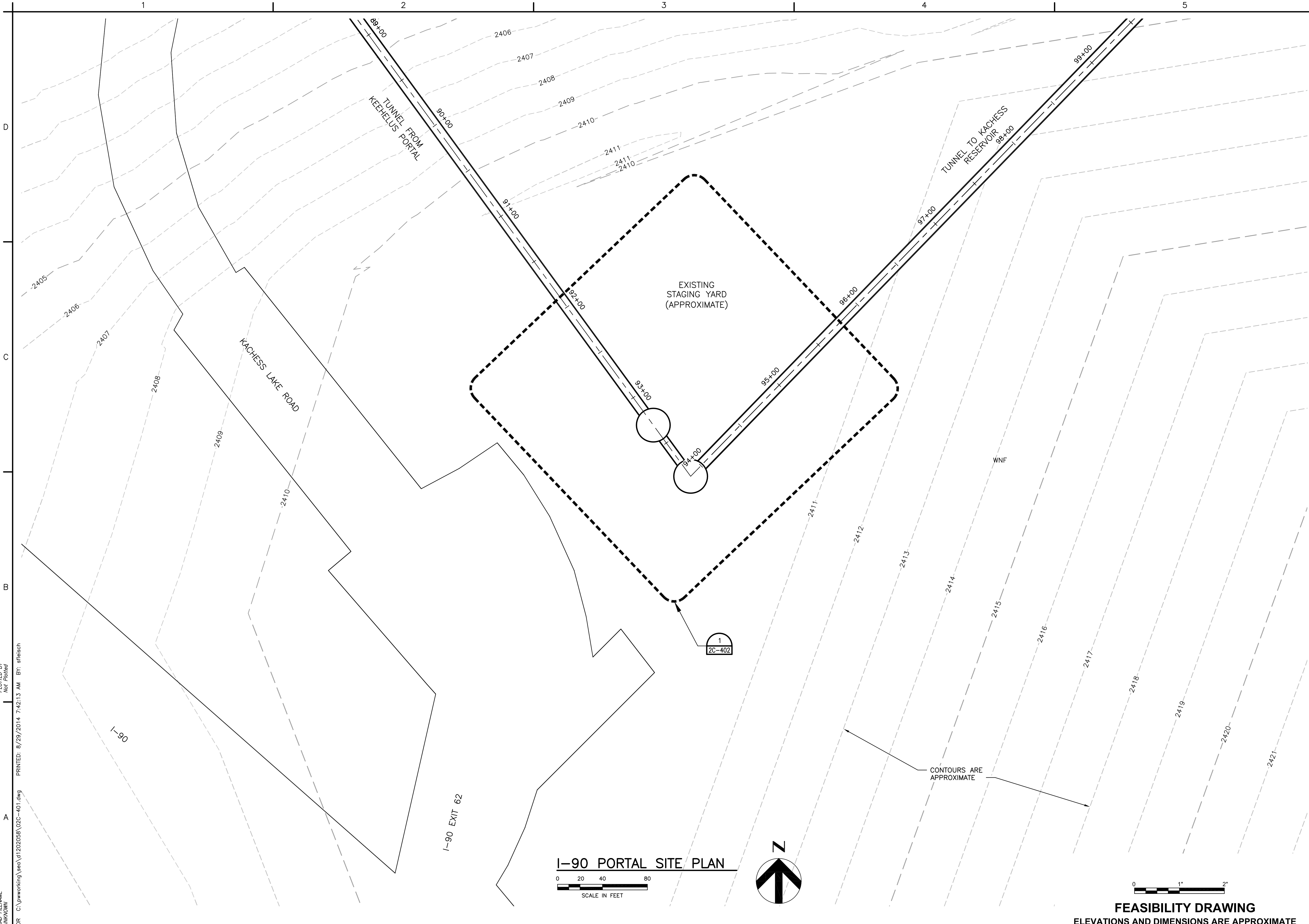

I-90 PORTAL SITE PLAN

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

0 1" 2"

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STATE OF WASHINGTON
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K. GOSS
DESIGNED

J. PETERSON
REVIEWED

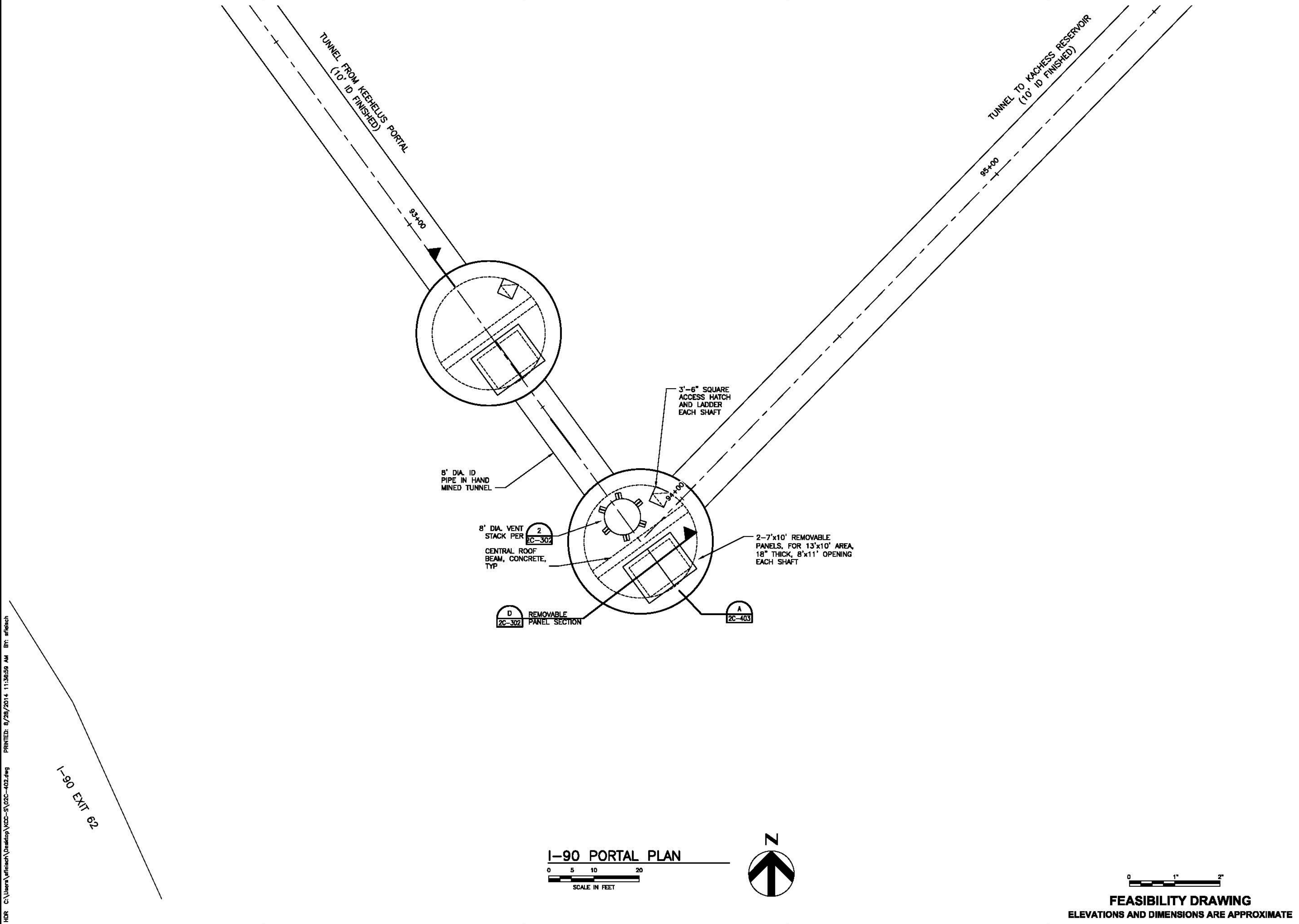
YAKIMA, WA 2014-08-20

I-90 PORTAL SITE PLAN

SOUTH TUNNEL ALIGNMENT

2C-401

SHEET 13 OF 18



FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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I-90 PORTAL ENLARGED PLAN

SOUTH TUNNEL ALIGNMENT

2C-402
SHEET 14 OF 18

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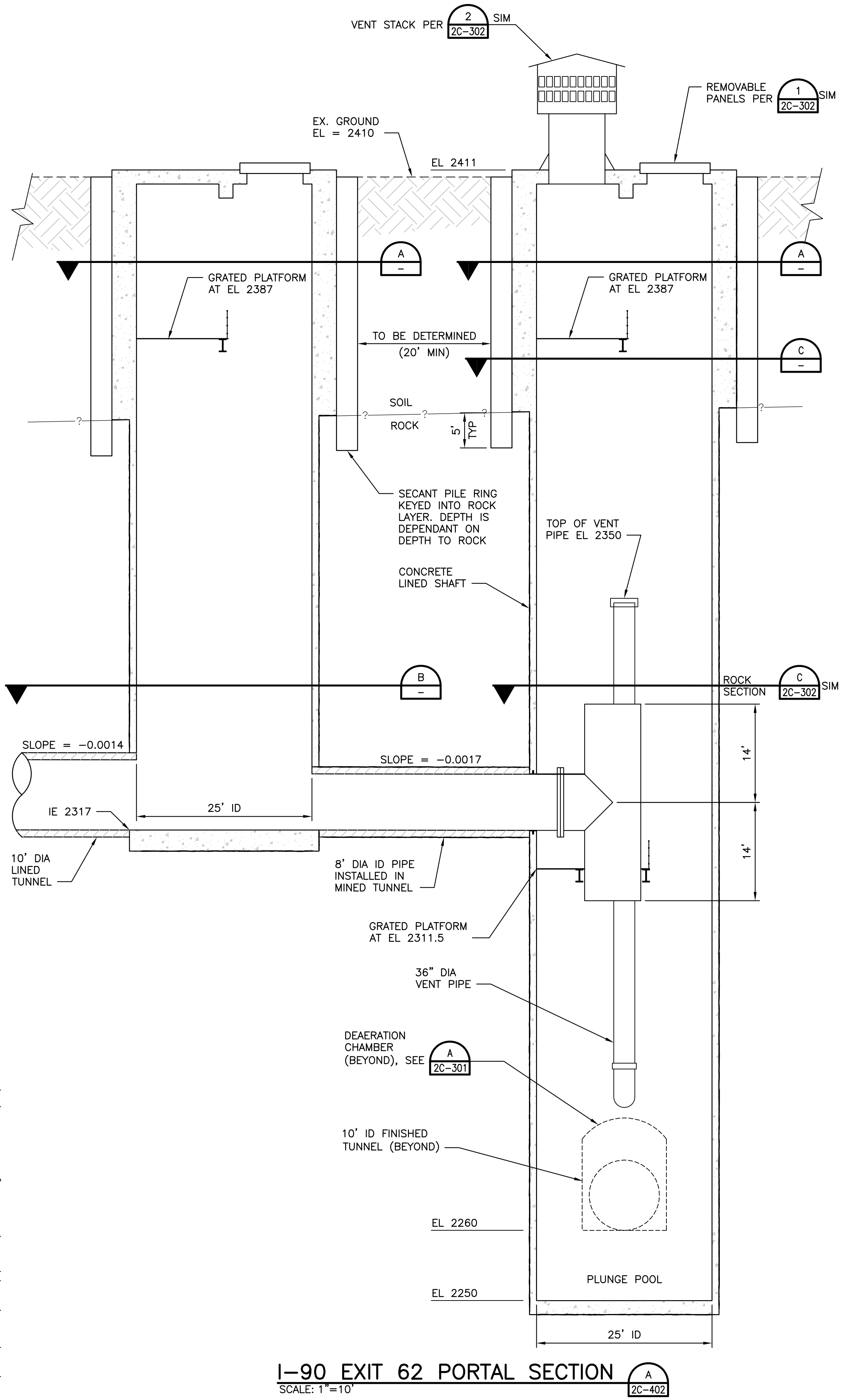
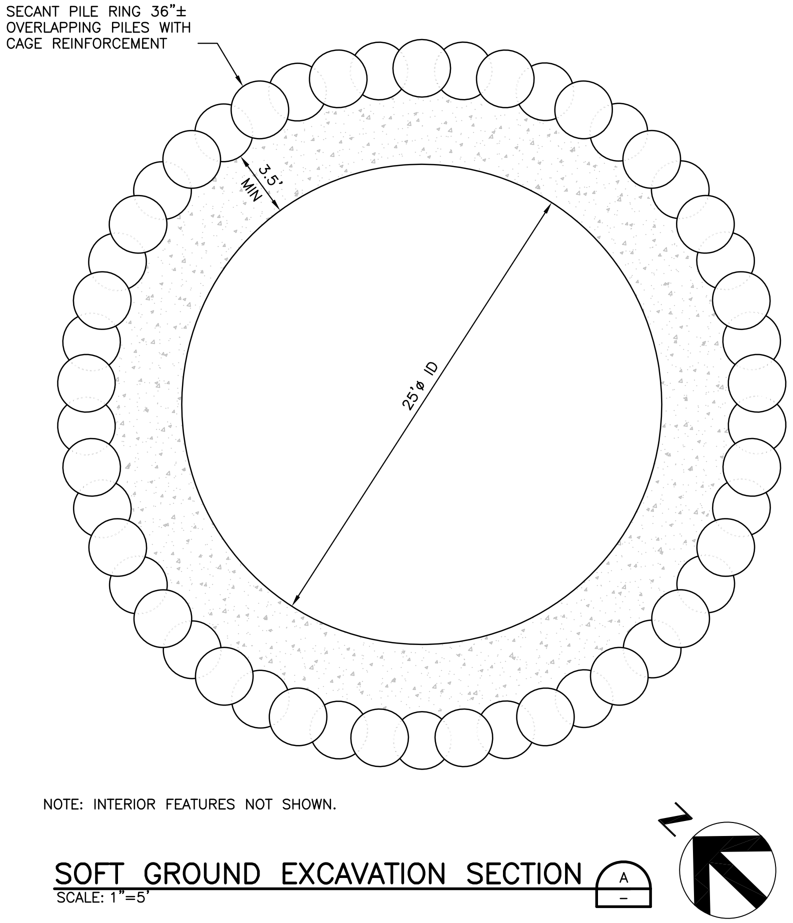
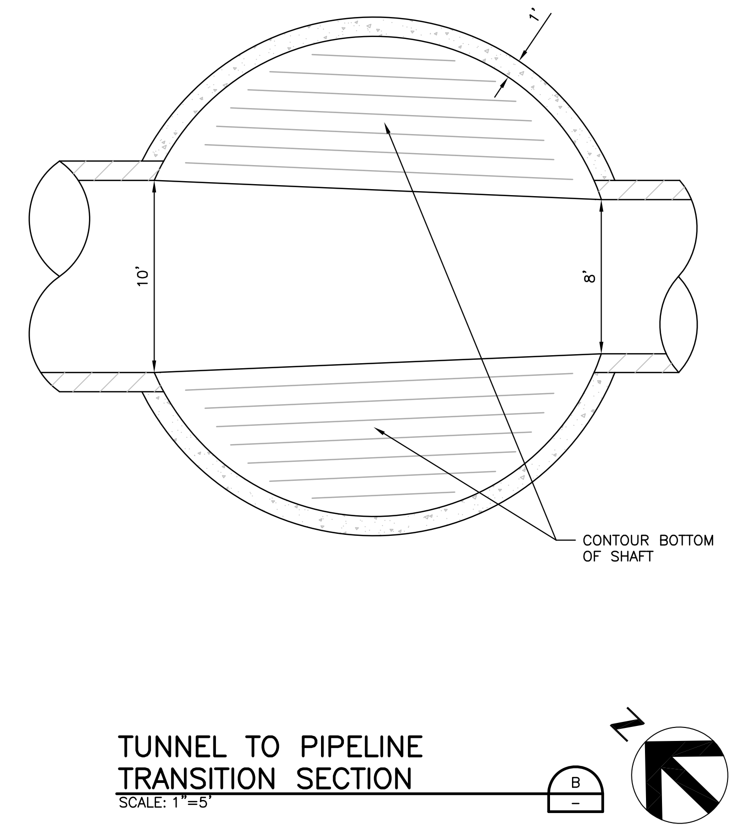


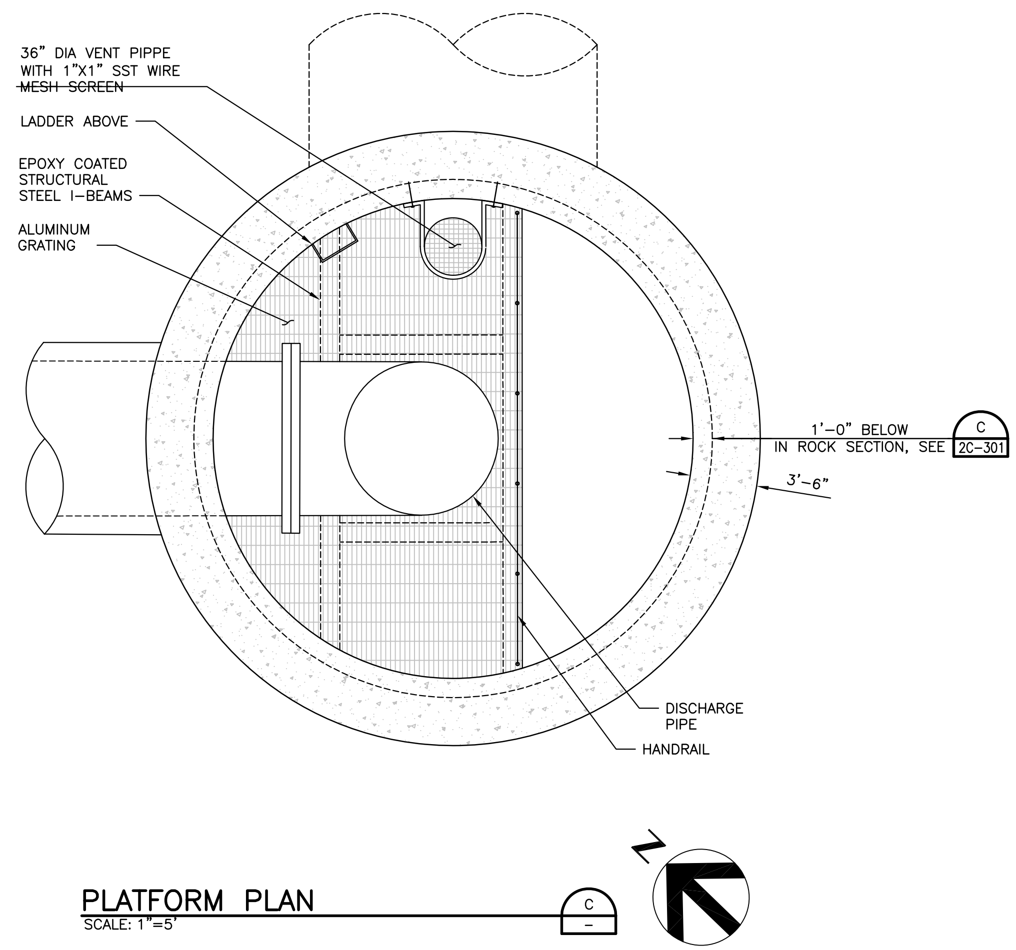
I-90 EXIT 62 PORTAL SECTION A 2C-402
SCALE: 1"=10'



SOFT GROUND EXCAVATION SECTION A
SCALE: 1"=5'



TUNNEL TO PIPELINE TRANSITION SECTION B
SCALE: 1"=5'



PLATFORM PLAN C
SCALE: 1"=5'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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S. RAJAH — DESIGNED
J. PETERSON — REVIEWED
YAKIMA, WA 2014-08-20

I-90 PORTAL SECTION AND DETAILS

SOUTH TUNNEL ALIGNMENT

2C-403
SHEET 15 OF 18

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CAD FILENAME UNKNOWN
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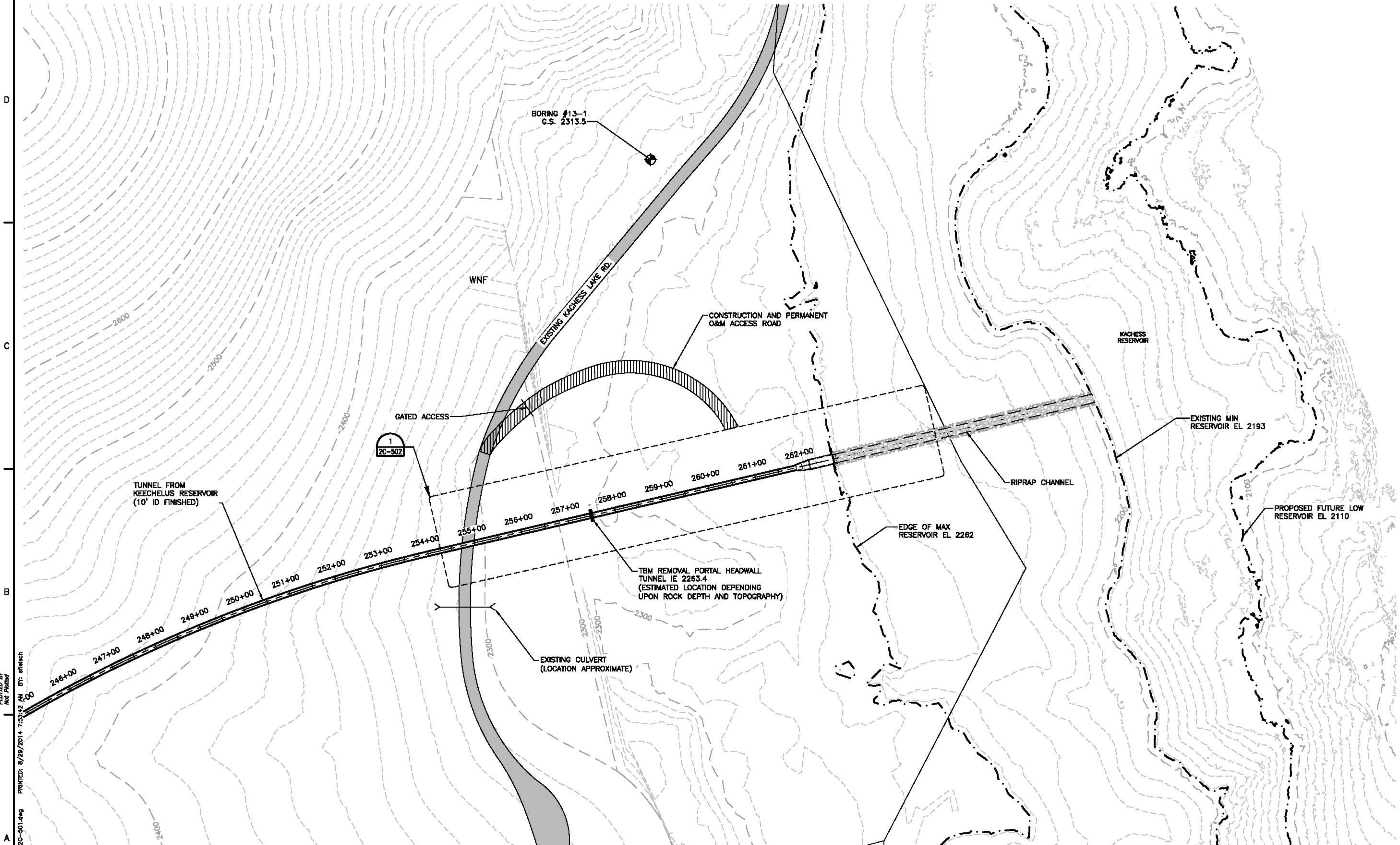

PORTAL AND TEMPORARY ROAD SITE PLAN

0 50 100 200
SCALE IN FEET

N

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

KACHESS RESERVOIR
PORTAL
SITE PLAN

SOUTH TUNNEL
ALIGNMENT

2C-501
SHEET 16 OF 18

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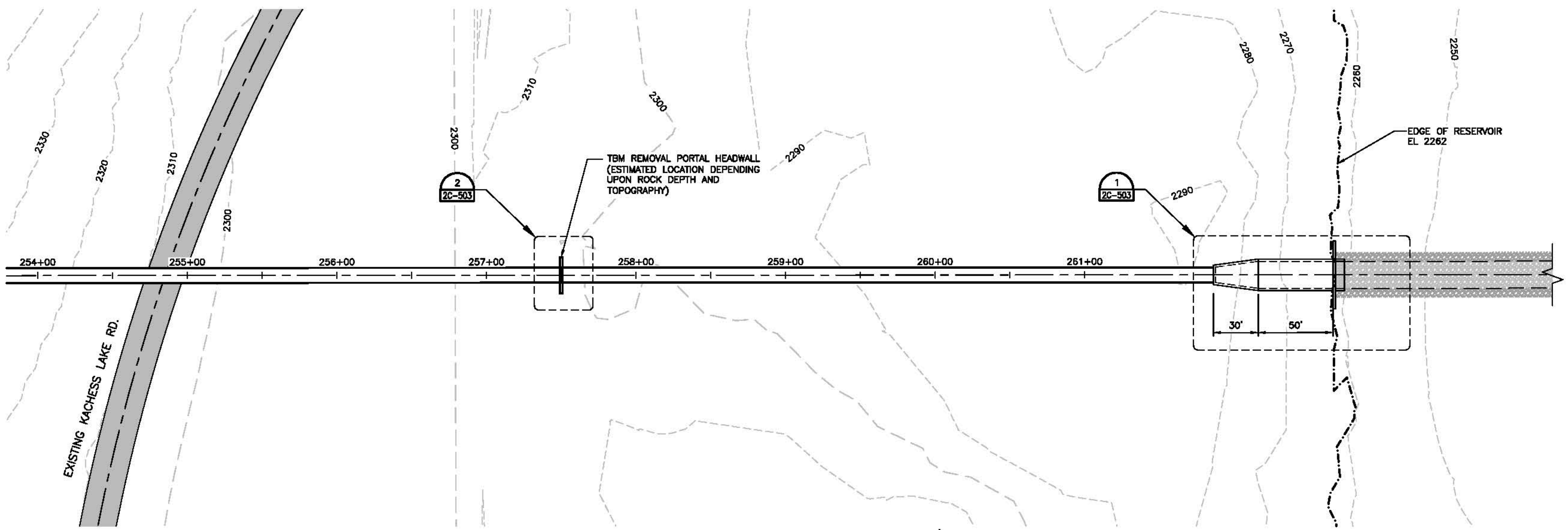
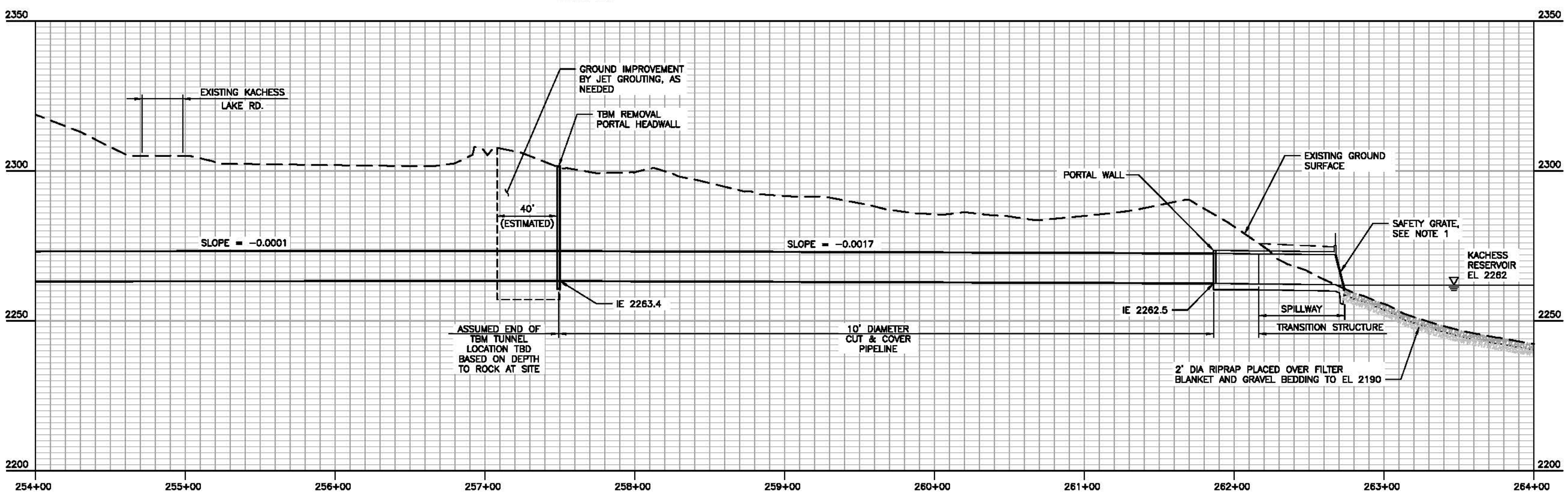


DISCHARGE PORTAL AND SPILLWAY PLAN

0 20 40 80 SCALE IN FEET



DISCHARGE PORTAL AND SPILLWAY PROFILE

SCALE: 1"=40' H; 1"=20' V

NOTES:

1. SAFETY GRATE SIZED TO EXCLUDE ENTRY BY PEOPLE AND LARGE ANIMALS, NOT YET DESIGNED.

FEASIBILITY DRAWING

ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED S. RAJAH

REVIEWED J. PETERSON

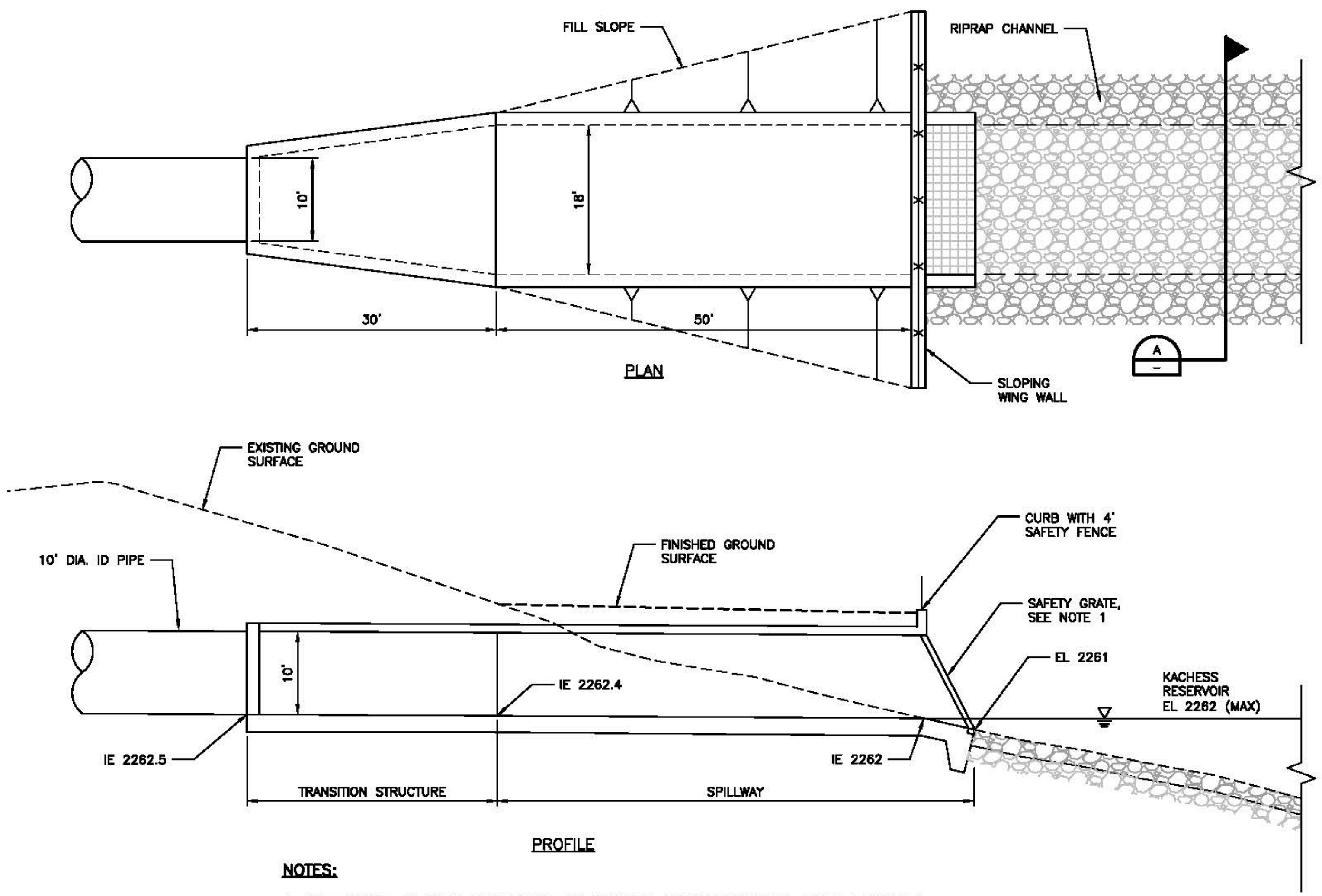
YAKIMA, WA 2014-08-20

KACHESS RESERVOIR PORTAL AND DISCHARGE STRUCTURE PLAN AND PROFILE

SOUTH TUNNEL ALIGNMENT

2C-502

SHEET 17 OF 18

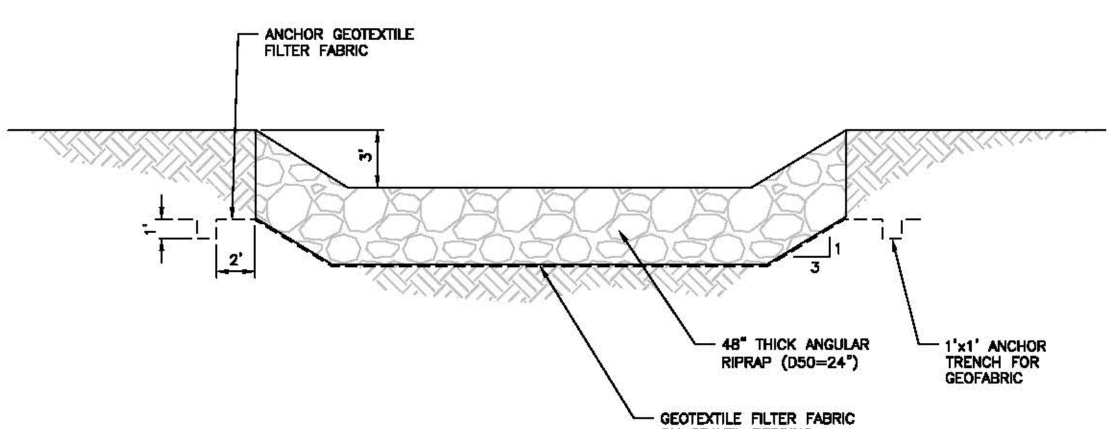


NOTES:

1. SAFETY GRATE SIZED TO EXCLUDE ENTRY BY PEOPLE AND LARGE ANIMALS, NOT YET DESIGNED.

DISCHARGE PORTAL AND SPILLWAY DETAIL (1 / 2C-502)

SCALE: 1"=10'



NOTE:
THIS RIPRAP SECTION ASSUMES AN ERODIBLE SOIL SUBSTRATE BELOW.

RIPRAP SECTION (A / –)

SCALE: 1"=5'

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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Managing Water in the West

HDR

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ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WA
KITTITAS DIVISION

KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED: S. RAJAH
REVIEWED: J. PETERSON

YAKIMA, WA 2014-08-20

KACHESS RESERVOIR PORTAL AND DISCHARGE STRUCTURE DETAILS

SOUTH TUNNEL ALIGNMENT

2C-503

SHEET 18 OF 18

Appendix C
Future Fish Passage Drawings

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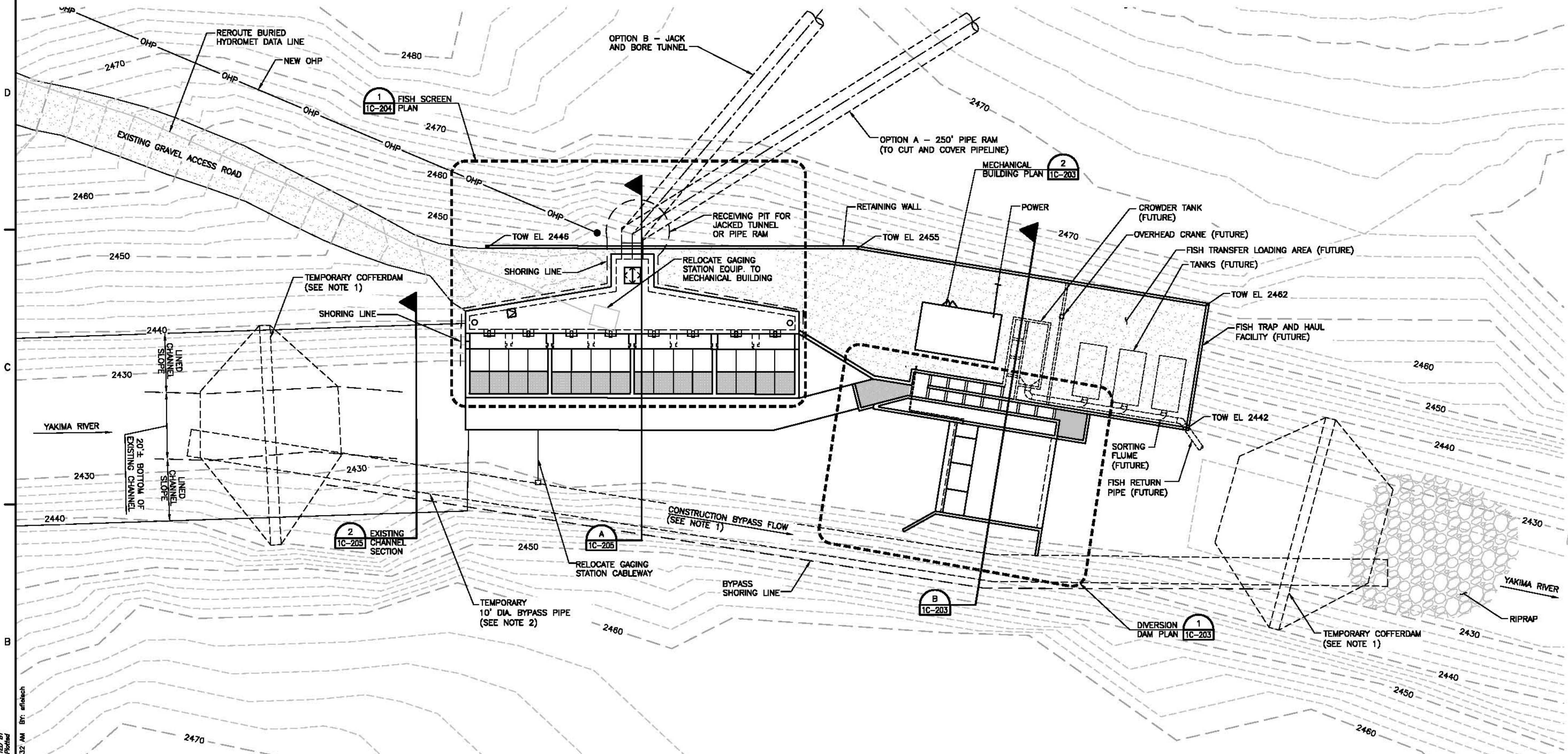

DESIGN CRITERIA

- MAXIMUM DIVERSION: 400 CFS
- MINIMUM POOL DEPTH: 7.0 FT
- SCREEN AREA: 1,150 SQ FT (4 BAYS, 29.25 FT LONG x 9.92 FT WIDE EACH)
- MAXIMUM APPROACH VELOCITY: 0.40 FPS
- MINIMUM 0.8 FPS SWEEPING FLOW
- ATTRACTION FLOW: 50 CFS
- TRAP AND HAUL WATER SUPPLY: 10 CFS (FUTURE)
- MINIMUM FISH LADDER FLOW: 20 CFS
- FISH LADDER MINIMUM POOL SIZE: 8 FT LONG x 6 FT WIDE x 5 FT DEEP
- AUTOMATED AIR BURST CLEANING

DIVERSION & INTAKE SITE PLAN 1 —

0 10 20 40
SCALE IN FEET

N

NOTES:

1. COFFERDAM AND RIVER BYPASS TO BE IMPLEMENTED BY CONTRACTOR. PIPE BYPASS IS ONE ALTERNATIVE. RELOCATION WILL BE REQUIRED DURING CONSTRUCTION TO ACCOMMODATE COMPLETION OF ADJUSTABLE CREST DIVERSION DAM AND SCREEN STRUCTURE.
2. BYPASS PIPE ALIGNMENT IS APPROXIMATE.

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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J. NELSON
DESIGNED

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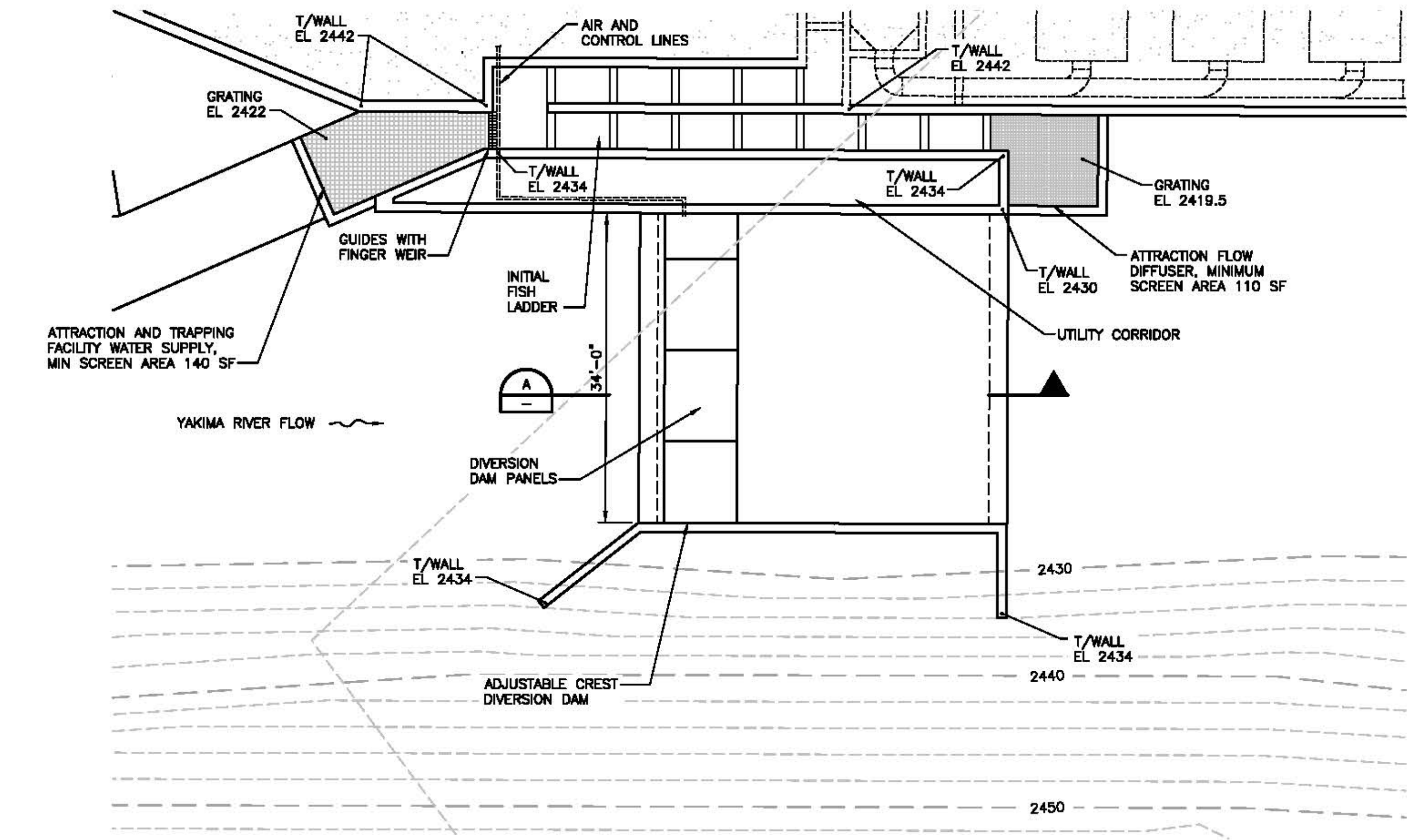
REVIEWED

YAKIMA, WA 2014-08-20

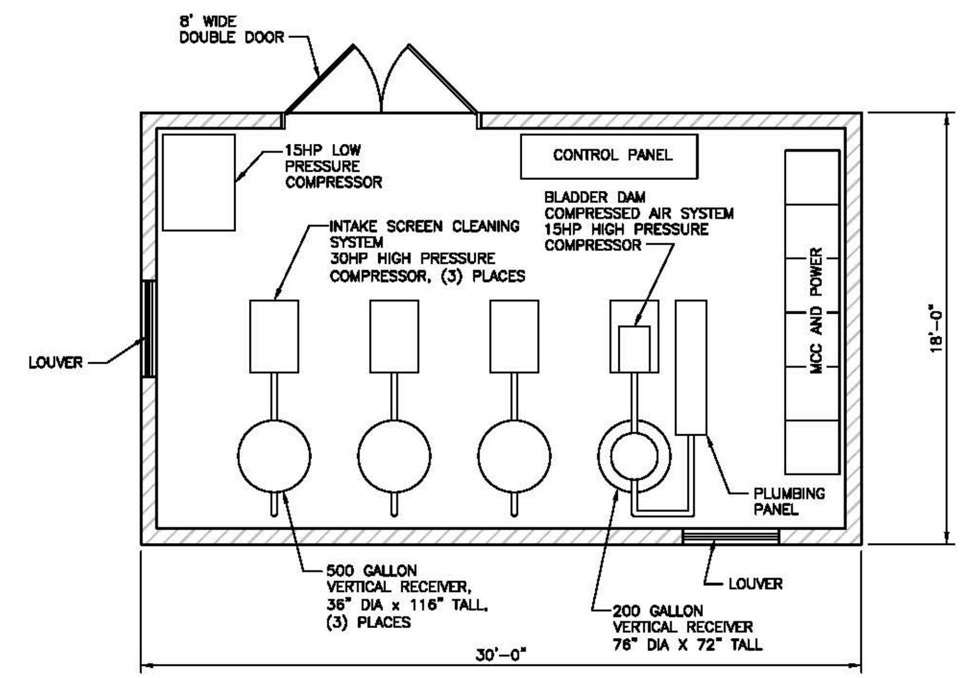
YAKIMA RIVER DIVERSION AND INTAKE SITE PLAN

NORTH TUNNEL ALIGNMENT

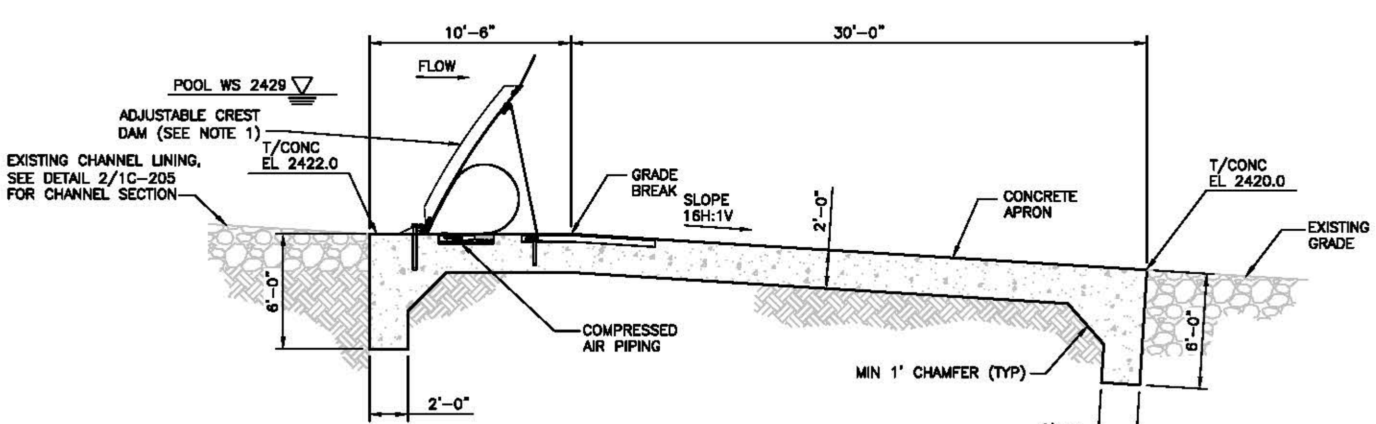
1C-202
SHEET 6 OF 17



DIVERSION DAM PLAN
SCALE: 1"=10'
1 1C-202

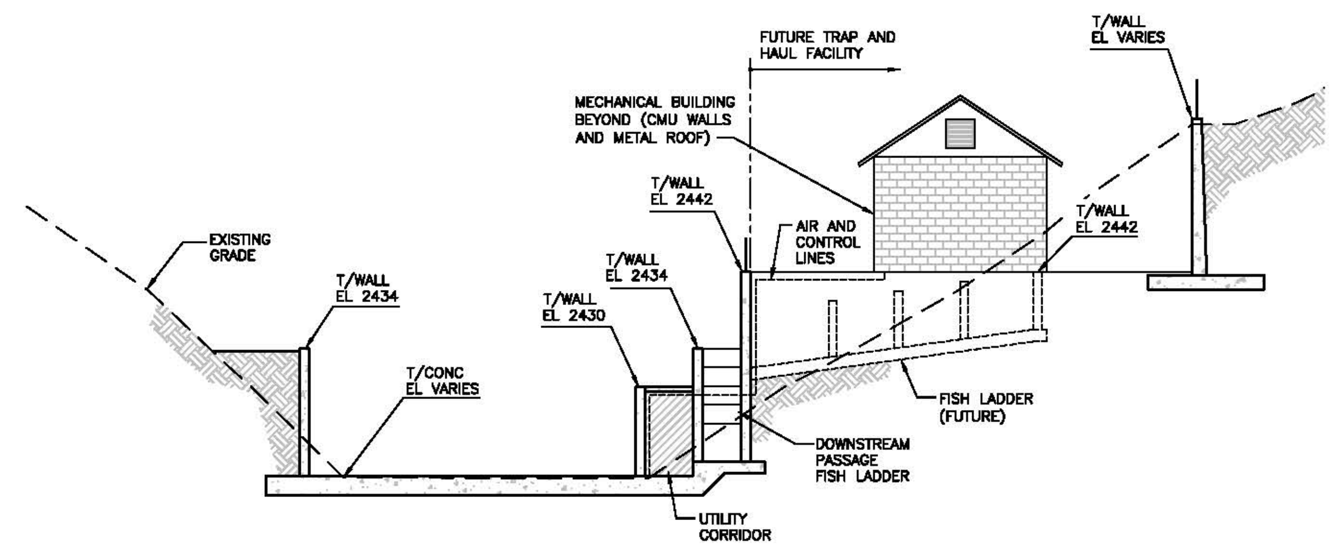


MECHANICAL BUILDING PLAN
SCALE: 1/4"=1'-0"
2 1C-202



NOTE:
1. INFLATABLE DAM SHOWN, BUT ANOTHER ADJUSTABLE DAM TYPE COULD BE USED.

DIVERSION DAM SECTION
SCALE: 1"=5'
A —



DAM SECTION
SCALE: 1"=10'
B 1C-202

0 1" 2"

FEASIBILITY DRAWING
ELEVATIONS AND DIMENSIONS ARE APPROXIMATE

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KEECHELUS RESERVOIR TO KACHESS RESERVOIR

DESIGNED J. NELSON
REVIEWED J. PETERSON
YAKIMA, WA 2014-08-20

YAKIMA RIVER DIVERSION DAM PLAN AND SECTION

NORTH TUNNEL ALIGNMENT

1C-203
SHEET 7 OF 17

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Appendix D
Feasibility Level Construction Schedules (Draft)

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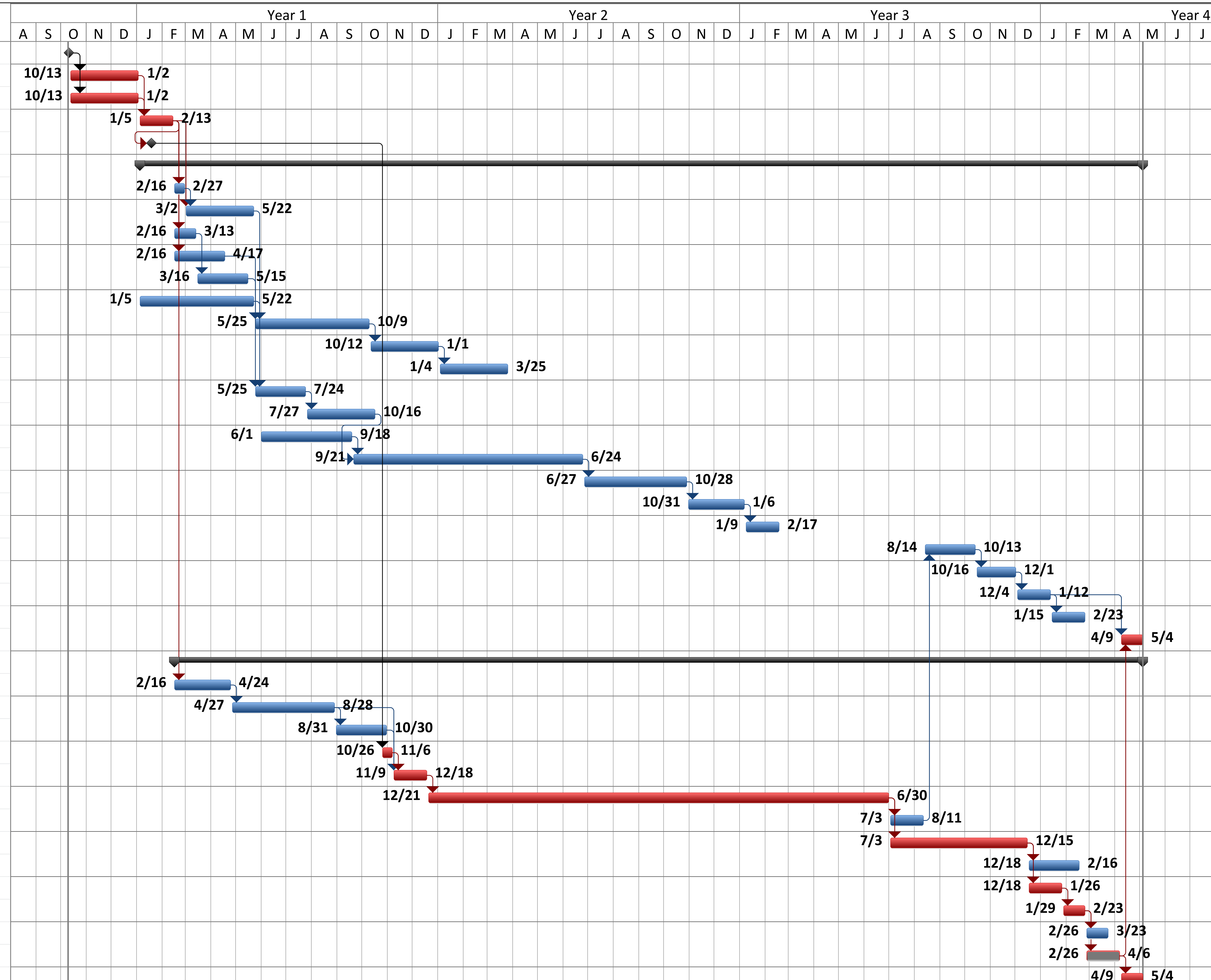
KKC North Tunnel Alignment

Fri 8/29/14 DRAFT

ID	Name	Duration
1	**Award/NTP**	**0 days**
2	Submittals	60 days
3	Permitting	60 days
4	Mobilization	30 days
5	Order TBM	0 days
6	**Keechelus Area Activities**	**870 days**
7	Install temporary Yakima River gauge	10 days
8	Install Yakima River cofferdams/diversion	60 days
9	Clear Keechelus Portal and intake sites	20 days
10	Install Keechelus dewatering system	45 days
11	Partially excavate Keechelus Portal shaft to rock	45 days
12	Procurement of 96-in Diameter Pipe	100 days
13	Install Keech Portal to Yakima River conveyance	100 days
14	Complete Keechelus Portal Shaft to deep tunnel depth	60 days
15	Drill and blast mine Keechelus deaeration chamber	60 days
16	Excavate for Yakima River dam, screens, and Intake	45 days
17	Yakima River diversion dam	60 days
18	Procurement of Fish Screens/Equipment	80 days
19	Yakima River fish screens and intake	200 days
20	Fish screen and dam support building and systems	90 days
21	Dam and fish screen mechanical systems	50 days
22	Systems controls and SCADA	30 days
23	Excavate Keechelus Portal plunge pool	45 days
24	Line Keechelus Portal shaft	35 days
25	Install Keechelus Portal appurtenances	30 days
26	Keechelus site cleanup and restoration	30 days
27	Operational startup and testing	20 days
28	**Kachess Portal Activities**	**840 days**
29	Clear and relocate Kachess Lake Rd	50 days
30	Kachess Portal site grading, and headwall	90 days
31	Kachess Portal starter tunnel	45 days
32	Receive TBM	10 days
33	Install TBM and begin tunnel mining	30 days
34	Tunnel Mining	400 days
35	Complete tunnel mining and remove TBM	30 days
36	Tunnel Lining	120 days
37	Kachess Portal discharge structure	45 days
38	First half of Kachess double box culvert	30 days
39	Restore and reopen Kachess Lake Rd	20 days
40	Complete Kachess double box culvert	20 days
41	Kachess spillway, stilling basin, and riprap	30 days
42	Kachess site cleanup and restoration	20 days



KKC South Tunnel Alignment

Fri 8/29/14 DRAFT

ID	Name	Duration
1	**Award/NTP**	**0 days**
2	Submittals	60 days
3	Permitting	60 days
4	Mobilization	30 days
5	Order TBMs	0 days
6	**Keechelus Area Activities**	**665 days**
7	Install temporary Yakima River gauge	10 days
8	Install Yakima River cofferdams/diversion	60 days
9	Clear Keechelus Portal and intake sites	20 days
10	Install Keechelus dewatering system	45 days
11	Partially excavate Keechelus Portal shaft to rock	45 days
12	Procurement of 96-in Diameter Pipe	100 days
13	Install Keech Portal to Yakima River conveyance	100 days
14	Complete Keechelus Portal Shaft to deep tunnel depth	60 days
15	Drill and blast mine Keechelus deaeration chamber	60 days
16	Excavate for Yakima River dam, screens, and Intake	45 days
17	Yakima River diversion dam	60 days
18	Procurement of Fish Screens/Equipment	80 days
19	Yakima River fish screens and intake	200 days
20	Fish screen and dam support building and systems	90 days
21	Dam and fish screen mechanical systems	50 days
22	Systems controls and SCADA	30 days
23	Excavate Keechelus Portal plunge pool	45 days
24	Line Keechelus Portal shaft	35 days
25	Install Keechelus Portal appurtenances	30 days
26	Keechelus site cleanup and restoration	30 days
27	Operational startup and testing	20 days
28	**I-90 Portal Activities**	**675 days**
29	Clear and prepare site	15 days
30	Excavate shallow portal shaft	45 days
31	Excavate deep portal shaft	75 days
32	Mine tunnel between shafts	45 days
33	Line portal shafts	45 days
34	Mine starter tunnels	55 days
35	Receive TBMs	20 days
36	Install Segment B TBM and begin tunnel mining	30 days
37	Tunnel Mining Segment B	320 days
38	Complete Segment B tunnel mining and remove TBM	30 days
39	Segment B tunnel lining	120 days
40	Install Segment A TBM and begin tunnel mining	30 days
41	Tunnel Mining Segment A	200 days
42	Complete Segment A tunnel mining and remove TBM	30 days
43	Segment A tunnel lining	70 days
44	**Kachess Portal Activities**	**725 days**
45	Construct portal access road	20 days
46	Clear and grade Kachess Reservoir portal site	20 days
47	Site excavation, headwall, and ground preparation	70 days
48	Cut and cover discharge pipeline (except by headwall)	30 days
49	Kachess Portal discharge structure	45 days
50	Kachess Reservoir riprap	30 days
51	Tunnel to pipeline connection	30 days
52	Kachess site cleanup and restoration	20 days