Yakima River Basin Study

Preliminary Assessment of Wymer Reservoir Downstream Conveyance and Energy Recovery Technical Memorandum

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ, Task 4.7

Prepared by

HDR Engineering, Inc.

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

March 2011

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1.0 Introduction

This technical memorandum describes the preliminary study and design of a 6-mile conveyance system from the proposed Wymer Reservoir to the Roza Diversion Dam in the Yakima River Canyon between Ellensburg and Yakima, Washington (see Figure 1).

The primary purposes of constructing the off-channel storage reservoir on Lmuma Creek would be to improve anadromous fish habitat, improve the water supply for proratable irrigation water rights, meet future municipal water supply demands, and potentially generate electricity from a new hydropower plant. The facilities described in this memorandum would contribute to fulfilling the primary purposes of the Wymer Reservoir by passing water between the reservoir and the Roza Canal and improving management of the Roza Canal diversions. This is especially important during dry years when irrigation water supply might otherwise be limited.

At this appraisal level, the conveyance project has a design flow of up to 1,000 cfs, which would pass through a series of two tunnels, a siphon, and a penstock, ending at a proposed new hydroelectric powerhouse near the Yakima River at the Roza Diversion Dam site. Discharge from the powerhouse would be conveyed across the Yakima River in an elevated flume and released to the Roza Canal at the existing Roza Canal intake structure.

When planning the conveyance alignment where it passes through the Burbank Creek drainage, the study team also considered potential future development of additional storage within the Burbank and Selah drainages to ensure water availability in dry years. Design of these additional storage features is not part of this study.

The report includes the following sections:

Section 2 – Design criteria used at this preliminary stage to size and lay out the project facilities

Section 3 – General geology of the region based on studies of surface geology types and previous knowledge of area geology

Section 4 – Preliminary facility design

Section 5 – General design and preliminary analysis methods used for facility sizing

Section 6 – Land ownership along the project footprint

Section 9 – Cost estimate notes

Section 8 – Additional studies and issues to be addressed, and suggestions for the future work required to move the project forward

Appendix – Appraisal-level drawings of key project features

(Note: The findings of the 2007 appraisal study of the proposed Wymer dam and reservoir project can be found in the Volume 2 technical memorandum, *Wymer Dam and Reservoir Summary*)

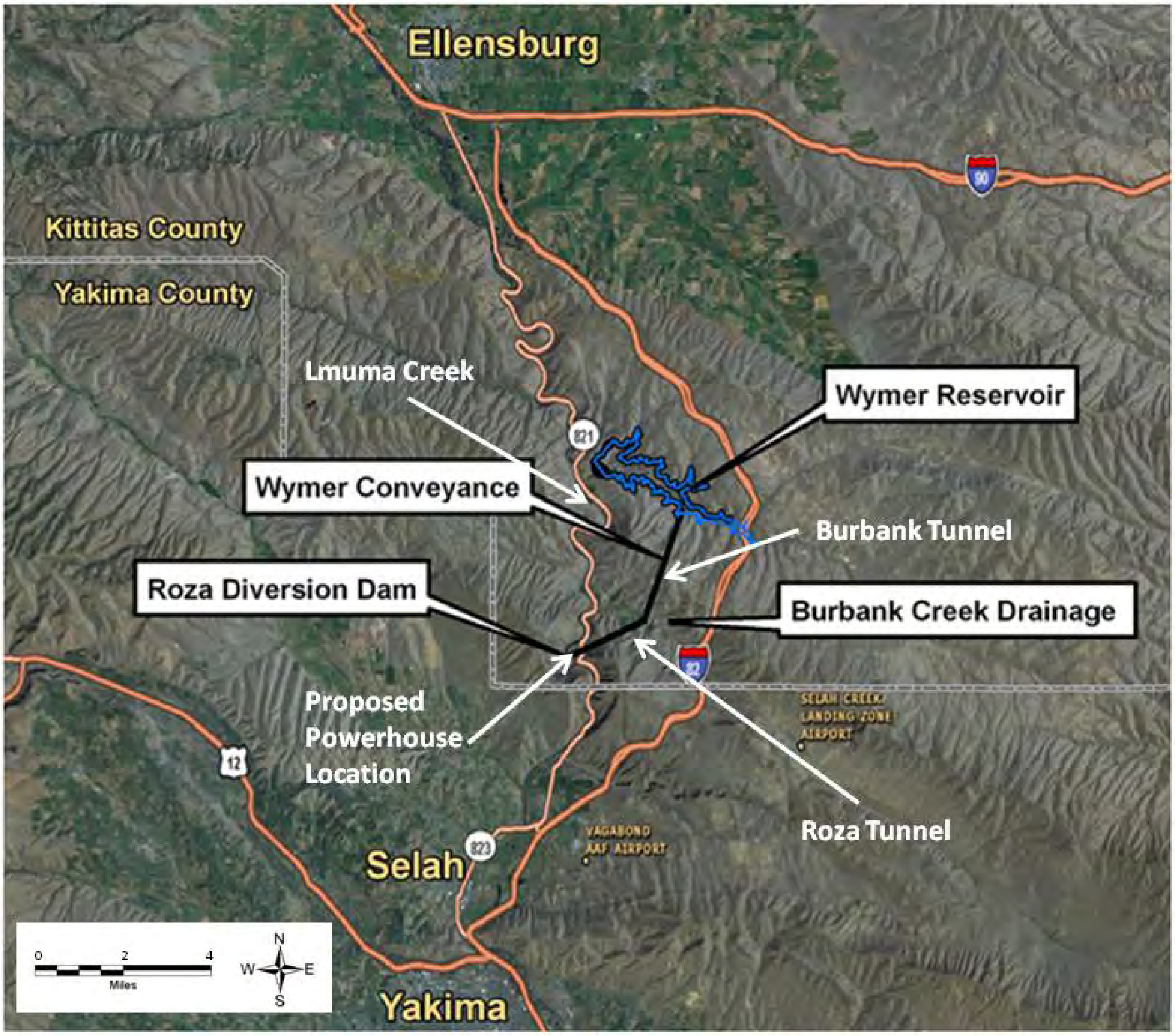

Figure 1. Proposed Wymer Reservoir Conveyance Project Area

2.0 Design Criteria

The appraisal-level study of the conveyance facilities was performed using available data. Further study would be required to properly identify the final design criteria used in the sizing and layout of the conveyance components and facilities. This would include detailed geotechnical investigation, predictions of operational flow duration and flow rate, accurate surveys, and quotes from equipment suppliers. Appraisal-level drawings of key project features described below can be found in the appendix.

2.1 Flow Transfer Rate

The flow criteria selected for the project is to convey up to 1,000 cfs from Wymer Reservoir to connect to the existing Roza Canal at the Roza Diversion Dam as agreed upon by both parties during initial discussions between HDR and Reclamation.

2.2 Wymer Reservoir Conveyance Intake

The type of intake structure would be selected based on topography, access, and ease of construction and maintenance. The intake structure will be controlled remotely. The intake site would be selected such that a straight tunnel could be constructed from Wymer Reservoir, through the side of Mt. Baldy to a location within the Burbank Creek drainage to the south. The selected arrangement would facilitate the filling of a potential reservoir within the Burbank Creek drainage should additional storage ever be required beyond that of Wymer Reservoir.

A self-cleaning trash rack at the intake would be required to keep debris out of the hydroelectric turbines. Fish screens are considered unnecessary since all inflow structures to the Wymer Reservoir would be constructed with fish screens.

2.3 Burbank and Roza Tunnels

The following criteria were used for the Burbank and the Roza tunnels:

- Sizing of each conveyance component would be determined based on considerations of flow, constructability, and headloss.
- Starting and ending elevations of the conveyance alignment would be chosen to minimize tunnel lengths while allowing for potential future water storage facilities within the Burbank Creek drainage and further conveyance to the proposed Selah Creek Reservoir site.
- Tunnels would be either horseshoe or modified horseshoe style, reinforced and concrete-lined.

2.4 Burbank Creek Siphon

The Burbank Creek siphon would be a steel pipe with wall thickness capable of withstanding full hydrostatic pressures and any additional pressures that may occur during a surge event. The siphon would be buried with at least 3 feet of cover.

2.5 Penstock

The size of the penstock would be determined based on considerations of flow, constructability, and headloss. It should be designed for full hydrostatic pressures, plus surge pressure at the powerhouse. The penstock alignment would be designed to minimize the cost and the need for removal of existing structures on the hillside above the diversion dam. The penstock would be buried with at least 3 feet of cover.

2.6 Powerhouse

The following criteria were used for the powerhouse:

- Powerhouse would be on the east side of the Yakima River at a location that minimizes required excavation and is located within a reasonable distance of the Roza Canal headworks
- Elevation would set as low in elevation as possible to maximize the design head through the hydroelectric turbine
- Powerhouse would be an enclosed structure with access to units and controls
- Power production equipment would include a single Francis turbine and associated generator, switchgear, controls, transformer and other required electrical and mechanical equipment

- A turbine shut off valve is required to stop flows to the turbine for maintenance or in case of emergency
- Powerhouse roof would feature a hatch for removal of turbine or generator vertically by crane
- Powerhouse structure shall meet local, State, and Federal building codes

2.7 Tailrace

The draft tube from the powerhouse would discharge to a rectangular elevated flume open to the atmosphere with at least 2 feet of freeboard. This flume configuration that bypasses the river and discharges directly into the headworks was initially selected in lieu of discharging to the river and taking the water back out at the headworks due to water-quality concerns. Other configurations may be considered during subsequent phases of the project. The slope of the elevated flume would be chosen to minimize depth to an acceptable level within the flume and in consideration for powerhouse placement and interconnection to the existing Roza Canal headworks.

3.0 Geology

The geology of the area that includes Wymer Reservoir, proposed conveyance alignments, and the powerhouse is shown on the USGS geologic map of the east half of the Yakima Quadrangle (Schuster 1994) and in a USGS hydrogeologic report (Jones et al. 2006). The Washington Division of Geology and Earth Resources (2005) published the same geologic mapping information in the form of GIS dataset layers. Figure 2 shows the geologic map for the proposed reservoir area and the Wymer siphon and tunnel alignments.

As summarized in Jones et al. (2006), the Yakima River Basin is part of the Yakima Fold belt, which is a highly folded and faulted region underlain by various consolidated rocks, ranging in age from Precambrian to Tertiary, and unconsolidated materials and volcanic rocks of Quaternary age. In the Yakima River Basin, the headwater areas in the Cascade Range include metamorphic, sedimentary, and intrusive and extrusive igneous rocks. The central, eastern, and southwestern parts of the basin are composed of basalt lava flows of the Columbia River Basalt Group (CRBG) with some intercalated sediments that are discontinuous and weakly consolidated. The lowlands are underlain by unconsolidated and weakly consolidated valley-fill composed of glacial, glacio-fluvial, lacustrine, and alluvium deposits exceeding 1,000 feet thick in places. Wind-blown deposits (loess) occur locally along the lower valley.

The Burbank Tunnel alignment primarily passes through surface geologic units of the CRBG, consisting of Wanapum basalt and Grande Ronde basalt. The Roza Tunnel passes through surface geologic units of CRBG, continental sedimentary deposits (Mc[e]), and mass wasting deposits (Qls). Based on the geologic information reviewed, it appears possible that the majority of the tunnel alignment and the shafts could be located essentially within the Basalt bedrock and the siphon alignment could be located within the Mc (e). A thrust fault or fold along several locations along the conveyance alignment has been mapped based on surface evidence. Detailed, site-specific geotechnical and geological investigations should be conducted at the locations of the proposed structures to confirm design assumptions and feasibility.

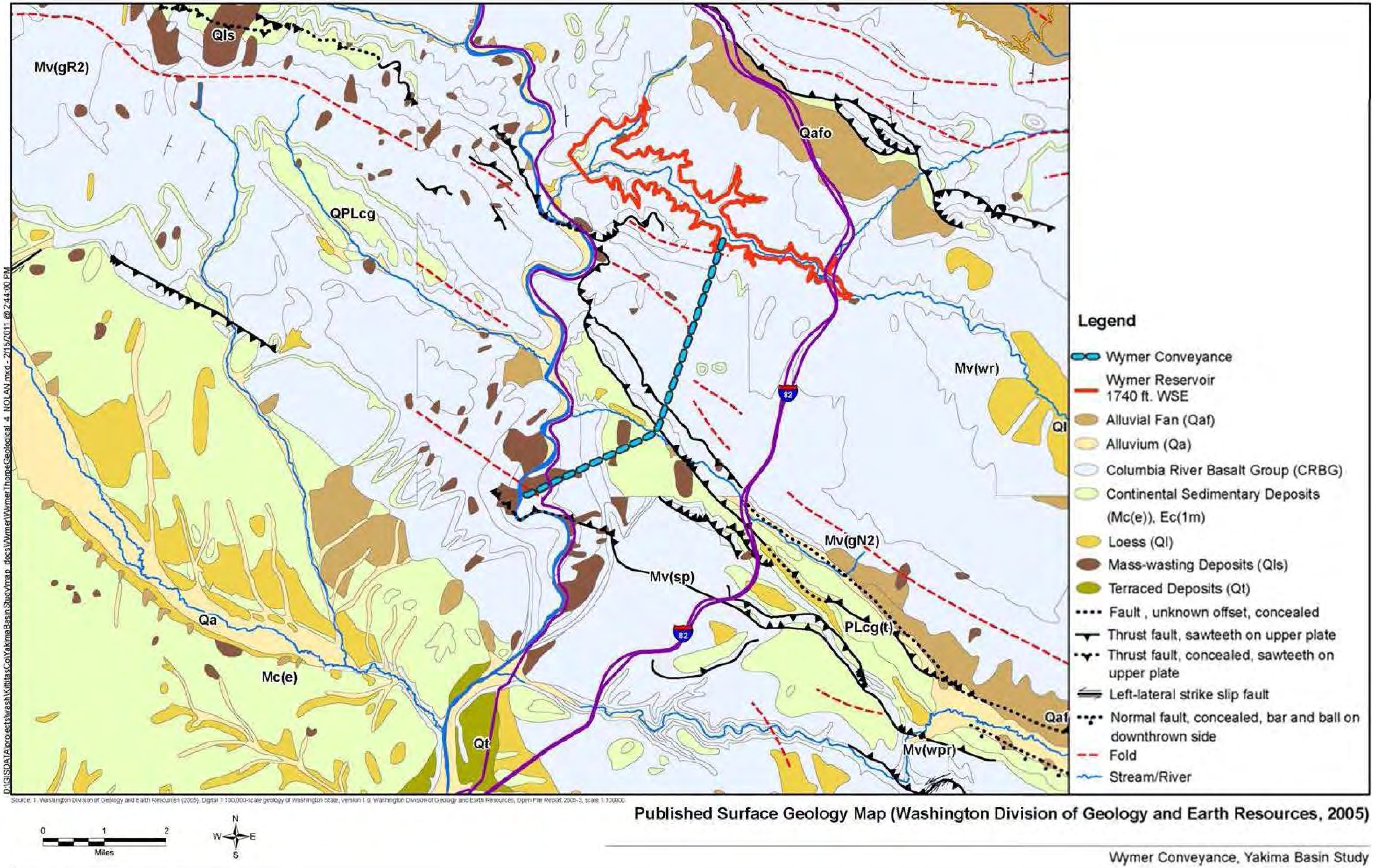

Figure 2. Surface Geology Map

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4.0 Facilities Description

This section describes the facilities required to convey water approximately 6 miles from the Wymer Reservoir site south to the Roza Diversion Dam. In summary, this project includes the following components (lengths are approximate):

- Intake structure
- 16,750 feet of tunnel (Burbank Tunnel)
- 930 feet of steel siphon pipeline (Burbank Creek Siphon)
- 8,750 feet of tunnel (Roza Tunnel)
- 3,100 feet of buried steel penstock
- Hydroelectric facility with a single Francis turbine
- Powerhouse tailrace in the form of an elevated flume spanning the Yakima River and connecting to the existing headworks for the Roza Canal

SR 821 would provide primary access to the Wymer area. New access and construction roads would be required to the intake structure, up the Burbank Creek Drainage, and for tunneling or penstock installation.

The Wymer Reservoir is a proposed off-channel storage facility consisting of a 450-foot-tall concrete faced rockfill dam with a second 180-foot-tall central core rockfill saddle dike. The embankments would inundate the Lmuma Creek drainage to a maximum water surface of 1,741.6 during the probable maximum storm event. The available storage volume would be approximately 125,000 acre-feet between elevations 1,600 feet and 1,730 feet. The active storage area is subject to change depending on outlet works configuration and the ultimate water plan for the project.

Initial studies of Wymer Reservoir included a plan to fill the reservoir from a pumping station along the Yakima River at the base of the dam and an option to divert water from the Yakima River at a pump station near Thorp. Water would be conveyed to the reservoir through a reconstructed Kittitas Reclamation District Canal through the Kittitas Valley and then routed through a series of tunnels and siphons to the reservoir site. Those facilities and the dam are the subjects of separate reports entitled the “Wymer Dam and Reservoir Summary Technical Memorandum” and the “KRD Canal Modifications Technical Memorandum.”

4.1 Conveyance Facilities

This section addresses the appraisal layouts for the conveyance intake structure, Burbank Tunnel, Burbank Creek siphon, Roza Tunnel, powerhouse and tailrace. For this level of study the elevations and alignments are based on high-level GIS mapping data. The sizing of the conveyance components are based on hydraulic requirements and previous experience with local geology. Any future studies would require detailed geotechnical investigations, predictions of operational flow duration and flow rate, accurate surveys, and quotes from equipment suppliers.

4.2 Intake Structure

The intake would be a concrete structure sloped at approximately 45 degrees along the hillside from the intake elevation to 10 feet above the maximum water-surface elevation of Wymer Reservoir. The structure would house a slide gate and access portal with allowance for a bulkhead gate. A hoist shaft would extend to a structure above the maximum water surface that would be built on structural fill extending into the reservoir. The inlet elevation of 1,600 feet was selected to provide 150,000 to 200,000 acre-feet of storage in the Wymer Reservoir and to provide an outlet elevation for the Burbank Tunnel where the tunnel would daylight within the proposed Burbank Creek Reservoir location.

The slide gate would be electrically or hydraulically operated and controlled remotely. A shaft or pipe would extend from the transition or tunnel downstream from the gate to above the maximum water-surface elevation to prevent damage to the tunnel and intake from vacuum conditions created when the slide gate is closed. The slide gate should be designed to close under full flow and head for protection of downstream facilities.

A trash rack would be installed at the face of the intake to keep debris out of the conveyance system. The trash rack may require a cleaning system, such as a traveling screen or rake. An air sparging system may be required if the depth is too great for other systems.

Site civil work would include removal of the overburden, excavating to sound bedrock as a foundation for the intake structure and for a stable environment for the tunnel boring machine (TBM). At this level of study it is assumed that there is approximately 10 feet of overburden material to be removed to reach competent rock

4.3 Burbank Tunnel

The Burbank Tunnel would connect Wymer Reservoir to the Burbank Creek Siphon in the Burbank Creek drainage. It would be 14 feet in diameter, horseshoe or modified horseshoe shaped, and approximately 16,750 feet long. The ultimate shape of the tunnel is subject to change depending on geotechnical findings and the ultimate project layout. A transition structure at the end of the tunnel would connect the tunnel and siphon. (See Burbank Tunnel plan and profile drawings 3 and 4 in the appendix).

The tunnel would pass a maximum of 1,000 cfs with a velocity of 6.2 feet per second, and drop 60 vertical feet, ending at the Burbank Creek drainage at a tunnel invert at elevation of 1,540 feet. The criteria for the alignment of the Burbank Tunnel and the 1,540-foot elevation were chosen to allow for direct discharge from Wymer Reservoir into a potential future reservoir in the Burbank Creek drainage. Maximum hydrostatic pressure in the tunnel would be less than 90 psi.

The tunnel would likely be excavated with a TBM, but could also be excavated using drill-and-blast methods. To allow for gravity-flow drainage during tunneling it would be advantageous to excavate in a positive grade direction. The current proposed alignment assumes that excavation would start at the Burbank Creek drainage. It is possible a portion of the tunnel spoils could be used for part of the fill required at the intake structure or dam site. Existing roads may need to be upgraded and new roads constructed to allow access to the site for the TBM.

For this analysis it was assumed that the tunnel would be concrete-lined rock for its entire length. Rock-bolting also may be required in some tunnel sections. The modified horseshoe shape was chosen from “Design of Small Dams” published by Reclamation, which states that the normal rule of thumb for liner thickness is 1 inch per foot of diameter for a minimally reinforced tunnel. For this project, the team assumed a 24-inch-thick lining with a moderate level of reinforcement.

Tunnel sizing, boring and lining methods, and related design criteria would have to be determined and refined after more information was obtained from a geotechnical investigation along the alignment.

4.4 Burbank Creek Siphon

The Burbank Creek siphon would be a 10-foot-diameter, steel siphon pipeline commencing at the transition from the Burbank Tunnel at an approximate elevation of 1,540 feet. The siphon would be buried under the Burbank Creek drainage, returning to an elevation of 1,540feet on the south side of the drainage where it transitions to the Roza Tunnel. The siphon alignment is generally perpendicular to the Burbank Creek drainage and minimizes horizontal angles at the transitions. The steel pipeline wall thickness would be designed to withstand a maximum pressure of approximately 250 feet of head (110 psi) at its lowest point within the drainage, plus additional considerations for surge and pipe handling and transport. (See siphon plan and profile, drawing 4 in the appendix).

The siphon would require an air relief/vacuum breaker gallery or standpipe to avoid damage to the tunnel and penstock downstream from the siphon. Different options for crossing the Burbank Creek drainage should be evaluated if the project moves forward. An elevated pipeline or routing the pipeline up the valley on grade would eliminate the requirement for the air release/vacuum breaker component and may prove more cost-effective after further investigation.

If needed, most of the siphon pipeline could be drained from the low point into Burbank Creek at the end of each season or for internal inspection.

4.5 Roza Tunnel

The Roza Tunnel would also be a 14-foot-diameter horseshoe or modified horseshoe shaped tunnel. It would run about 8,750 feet from the transition at the Burbank Creek siphon to the penstock on the hillside above the Roza Diversion Dam at a tunnel invert elevation of 1,500 feet. (See Roza Tunnel plan and profile, drawings 4 and 5 in the appendix.) The tunnel would pass a maximum of 1,000 cfs with a velocity of 6.2 feet per second and drop 40 vertical feet. Maximum hydrostatic pressure within the tunnel would be less than 110 psi.

The tunnel would likely be excavated using a TBM, but could also be excavated using drill-and-blast methods. To allow for gravity-flow drainage during tunneling it would be advantageous to excavate in a positive grade direction. This alignment assumes that excavation would start at the downstream end of the tunnel on the hillside above the Roza Diversion Dam. A new road from SR 821 would provide access to the site for the TBM and installation of the upper portion of the penstock.

For this analysis it was assumed that the tunnel would be concrete-lined rock for its entire length. As with the Burbank Tunnel, the lining would be 24 inches thick. Rock-bolting also may be required in some tunnel sections. Tunnel sizing, boring and lining methods, and related design criteria would have to be determined and refined after more information was obtained from a geotechnical boring program along the alignment.

The Roza Tunnel would transition to a buried 9.5-foot-diameter steel penstock at an approximate elevation of 1,500 feet on the hillside above Roza Diversion Dam. The 3,100-foot penstock would run approximately 3 feet below existing grade under SR 821 and terminate at the powerhouse adjacent to the Yakima River near the existing Roza Dam maintenance facility. The alignment would avoid removal of existing structures where possible. The steel penstock would be designed to withstand up to 500 feet of head (217 psi) plus an allowance for surge. A future economic analysis of penstock sizing may determine that the cost of a slightly larger penstock would be offset by the additional energy generation made possible by the lower headloss.

A short segment of SR 821 would need to be demolished and reconstructed for penstock installation. Access roads to the penstock would be adjacent to the penstock trench. Slopes along the alignment are gradual and do not pose a problem for access by heavy machinery.

4.6 Powerhouse

The preliminary powerhouse layout includes a single-unit Francis turbine capable of generating up to approximately 30 megawatts of power at the design flow of 1,000 cfs (see Section 5.5 for power calculations and a discussion of uncertainties associated with this preliminary calculation.)

The 46-by-65-foot powerhouse would have a concrete foundation and metal building structure. It would be adjacent to the Yakima River near the existing Roza Dam maintenance building, but partially buried in the hillside. The powerhouse location and configuration of the discharge eliminates the need for a cofferdam during construction. Excavation into the bedrock would be required for the powerhouse foundation. (See powerhouse plan and sections, drawings 8 and 9 in appendix.)

The powerhouse has been sized large enough to house the turbine, generator, switchgear, controls transformer, and other electrical and mechanical equipment. The generator step-up transformer would be outside the powerhouse. For the appraisal analysis it is assumed that the existing transmission lines servicing the diversion dam can be upgraded so no new transmission lines would be needed.

The turbine centerline elevation of 1,248.5 feet was chosen based on the appraisal design of the elevated flume described in section 4.3.4 and a preliminary calculation of the required unit submergence below the tailrace water surface to avoid cavitation of the turbine runner. This turbine centerline elevation results in a maximum gross head of about 480 feet (208 psi).

Access to the turbine or generator would be through a removable roof hatch that would allow removal vertically by crane. The powerhouse site would be accessed by the existing road to the diversion dam. A new access road for the existing Roza Diversion Dam may be required, depending on the elevation of the elevated flume.

A turbine shutoff valve would stop flows to the turbine for maintenance or in case of emergency. The draft tube would discharge into a small basin adjacent to the powerhouse before transitioning into the elevated flume.

Any future studies would require detailed geotechnical investigations and predictions of operational flow duration and flow rate to more accurately design the powerhouse and size power generation equipment. Consideration should be given to using historical Roza Irrigation District diversions modified during drought-year flows to reflect a minimum of 70% prorationing.

4.7 Tailrace

A 20-foot-wide, rectangular, reinforced-concrete flume would convey the design flow rate of 1,000 cfs with approximately 6 feet of water depth. A minimum of 2 feet of freeboard would result in finished inside flume dimensions of 20 feet by 8 feet. For the appraisal design the flume is about 10 feet above the normal operating pool elevation of the small reservoir created by the diversion dam. (See flume plan and profile, drawing 7 in the appendix.)

The elevated flume would be supported by a double-T bridge support system spanning approximately 100 feet between support piers. Two circular reinforced concrete piers would be set into the bedrock under the river bed. (See appraisal flume cross-section, drawing 10 in the appendix.)

A structural analysis was not performed for this study and would need to be included in future studies along with other considerations such as wind load, exact clearance requirements for the elevated flume over the river to accommodate flood flows, and other structural design requirements.

4.8 Roza Canal Headworks

The flume would be elevated approximately 10 feet above the existing water surface within the existing Roza Canal intake pool, with water velocities of approximately 8feet per second. A simple chute and stilling basin with energy-dissipating features would be required to reduce flow velocities before entering the existing Roza Canal intake pool. Hydraulic energy dissipation calculations were not performed for this appraisal-level study.

4.9 Other Facility Design Considerations

Sediment Handling

Velocities in the tunnels and siphon would minimize sediment build-up in the conveyance system. Although sediment could be an issue for the intake, the reservoir level would drop below the intake level at 1,600 feet elevation on an annual or semi-annual basis, allowing access for sediment removal, trash-rack cleaning and other maintenance activities.

Sediment may be a concern in the tailrace pool where velocities may be slow enough to settle out fines. The assumed limited time of operation during the year would allow ample time for maintenance crews to remove any sediment build-up that may occur.

Construction Access and Power

Primary construction access would be on local roads to and from SR 821. New access roads would be required to the intake site, to the access points for the Burbank and Roza tunnels in the Burbank Creek drainage, and on the hillside above the Roza Diversion Dam.

Low-voltage power from local service lines is available in some locations for construction needs, but the remote nature of the tunnel would require generators in many locations.

Metering and Controls

The facilities would include provisions for both local operation and remote control and monitoring. Monitoring equipment and controls would be required at the intake in Wymer Reservoir. The hoist system for the slide gate would be controlled at the gate, at the dam, and at the powerhouse. When the slide gate is open, the flow would be metered and controlled at the powerhouse.

The penstock and powerhouse would have automated data acquisition systems. Flows entering the powerhouse would be metered and controlled by the turbine mechanical equipment. A turbine shutoff valve would shut down the turbine in case of emergency or for maintenance. During an event when the turbines are out of service, the automated system would open the bypass valve to allow continued conveyance of water to the Roza Canal. No preliminary design work was done on the bypass system for this study. This work will be completed if the project advances.

Security

It is expected that security measures would be required for all project structures and access points. These would include fencing, intrusion sensors, remote-camera monitoring, and building alarm systems.

Hydraulic Surge Control

Because of the lengthy conveyance facilities and large water volumes, a synchronous bypass valve and/or large surge tank or chamber may be required near the powerplant to control and minimize surge pressures in the event of a rapid change in turbine flow. Such an event might occur during an emergency shutdown of the hydroelectric facility. Surge control would be considered in the placement and selection of air release/vacuum breaker equipment or structures.

5.0 Analysis/Preliminary Design

5.1 Hydraulic Analysis

The design flow of 1,000 cfs was used for hydraulic calculations through components of the conveyance system and powerhouse. The components were sized using an appraisal-level trade-off analysis between tunnel diameter and frictional losses. Table 1 shows the resulting head loss calculations for each component. All head-loss calculations were performed using methods from the Reclamation publication "Design of Small Dams."

Table 1. Summary of Head Loss Calculations

COMPONENT	HEAD LOSS (FEET)
Trash Rack and intake	0.37
Burbank Tunnel	10.35
Transition to Siphon	0.19
Siphon/Overland Penstock	2.90
Transition to Tunnel	0.96
Roza Tunnel	5.40
Transition to Penstock	0.25
Penstock	12.77
Siphon and Penstock Bends	2.80
Exit Losses	0.01
Total Head Loss	36.00

5.2 Tunnel Section

The modified horseshoe shape tunnel was chosen from the various configurations historically produced. For this study a 24-inch-thick liner was assumed with a moderate level of reinforcement.

5.3 Pipe Design

The preliminary calculation of maximum operating pressure for the steel siphon – 250 feet of head (110 psi) – results in a minimum wall thickness of 0.46 inches when taking into account transient pressures. The preliminary calculation of the maximum transient pressure within the penstock – 500 feet of head (217psi) – results in a minimum wall thickness of 0.9 inches when also accounting for transient pressure. The minimum thickness at the transition from the Roza Tunnel is 0.9 inches. The pipe would most likely be constructed with several different pipe thicknesses to reduce cost.

5.4 Flume Design

The flume was designed to be 20 feet wide with a water depth of approximately 6 feet and velocity of less than 10 feet per second. The calculated slope using Manning's equation was very gradual at 0.00943 feet per foot, resulting in minimal elevation drop as the flume spans the river.

The support system for the flume would consist of two standard double-T supports spanning up to 100 feet and supported by two round piers. This preliminary design is based on previous experience with bridge-support design. A structural analysis was not performed.

5.5 Power Plant Sizing

The power rating of approximately 30 megawatts for the single Francis turbine mentioned in the facility description (Section 4.1.7) is based on the normal maximum pool elevation of 1,730 feet, a tailrace water-surface elevation of 1,250 feet, a total head loss of 36 feet (Table 1), and a flow of 1,000 cfs. The calculation also used a conservative overall efficiency of 70%.

It is unlikely that this would be the final design power rating since there is currently no information on several factors that help determine power output. The most important factor is the planned rates and timing of flow through the year. This could result in a configuration of two or more units which, in turn, would change the powerhouse layout. Consideration should be given to using historical Roza Irrigation District diversions modified during drought-year flows to reflect a minimum of 70% prorationing. More detailed studies are required before a more accurate power output can be identified.

5.6 Hydropower Revenue Estimate

An opinion of average annual energy was developed for the proposed power plant during a water-use modeling study using RiverWare, the river and reservoir modeling application. The flows used to develop the estimated energy production represented in the study were those required to meet the entire Roza Irrigation District demand. The powerhouse could produce as much as 89,000 megawatts per hour annually at 6 cents per kilowatt-hour, with gross annual revenue as high as $5.3 million. This is considered to be gross revenue without accounting for renewable energy credits, capacity credits, wheeling charges, or operation and maintenance costs.

The final configuration of the powerhouse is likely to change with further study, and the estimated project energy and annual revenue would be subject to change due to power sales agreements, water availability, and the ultimate project configuration. As stated above, flows through the powerhouse may not represent the final distribution of water for the basin. The amount of water that would reach the powerhouse will be unknown until Reclamation decides which project elements to pursue and ultimately build. In addition, future studies must also consider any plans for the use of the existing powerhouse at canal mile 11.

6.0 Property Easements and Purchases

The Kittitas County Assessor’s website was used for a cursory evaluation of property ownership data. The tunnel and siphon would primarily cross private ranch land. Right-of-way would be required for 4.75 miles of tunnel, 900 feet of siphon, 0.5 mile of penstock, 600 feet of flume, and the powerhouse, which is approximately 5,900 square feet. The existing Roza diversion structure is owned by Reclamation.

For this appraisal study, property acquisition is based on the following assumptions:

- Parcels where the pipelines cross open space would need a 50-foot permanent easement and a 100-foot temporary easement.
- Parcels where the tunnel would cross would need a 50-foot permanent easement.
- All access roads would require permanent easements.
- Staging and laydown areas would require temporary easements.

Table 2 shows the breakdown of easements that would be required for the conveyance project.

Table 2. Summary of Easement Acreages

ITEM	PUBLIC LANDS (ACRES)		PRIVATE LANDS (ACRES)	
	PERMANENT	TEMPORARY	PERMANENT	TEMPORARY
Burbank Tunnel	14.5	-	4.2	-
Burbanks Creek Siphon	1.1	1.1	-	-
Roza Tunnel	2.4	-	7.6	-
Powerhouse Penstock	2.2	2.2	1.1	1.1
Powerhouse	1.0	-	-	-
Tailrace (including flume over river)	0.6	0.6	-	-

7.0 Cost Estimates

Cost estimates for the Wymer conveyance project are presented in the Volume 2 technical memorandum, "Opinions of Probable Construction Cost Technical Memorandum."

8.0 General Considerations

The challenges to implementing this project include the following:

1. Determining the feasibility of the concepts once water use is better defined
2. Construction of two long tunnels and a large-diameter siphon across Burbank Creek
3. Construction of an elevated flume across the Yakima River
4. Connection to existing Roza Diversion Dam headworks facilities
5. Determining feasibility of hydropower without definitive operational criteria and hydraulics or power sales agreements
6. Facilities and conveyance design without a geotechnical investigation

Next steps would include:

1. Confirm the system operational criteria and hydraulics. Model the hydraulics in more detail once the frequency and volume of flow is better defined by modeling of basin water availability and demands.
2. Perform geotechnical exploration and testing to determine if the proposed project could be feasibly constructed.
3. Perform a more detailed power revenue analysis.
4. Perform a more detailed feasibility study with the above steps.

9.0 References

Schuster, J.E., 1994. "Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington." Washington Division of Geology and Earth Resources. Open File Report 94-12, June.

Jones, M.A., Vaccaro, J.J., and Watkins, A.M., 2006. "Hydrogeologic Framework of Sedimentary Deposits in Six Structural Basins, Yakima River Basin, Washington." Prepared in Corporation with the Bureau of Reclamation, Washington State Department of Ecology, and Yakama Nation, U.S. Geological Survey Scientific Investigations Report 2006-5116, 24 p.

Washington Division of Geology and Earth Resources, 2005. Digital 1:100,000-scale geology of Washington State, version 1.0: Washington Division of Geology and Earth Resources, Open File Report 2005-3, scale 1:100000.

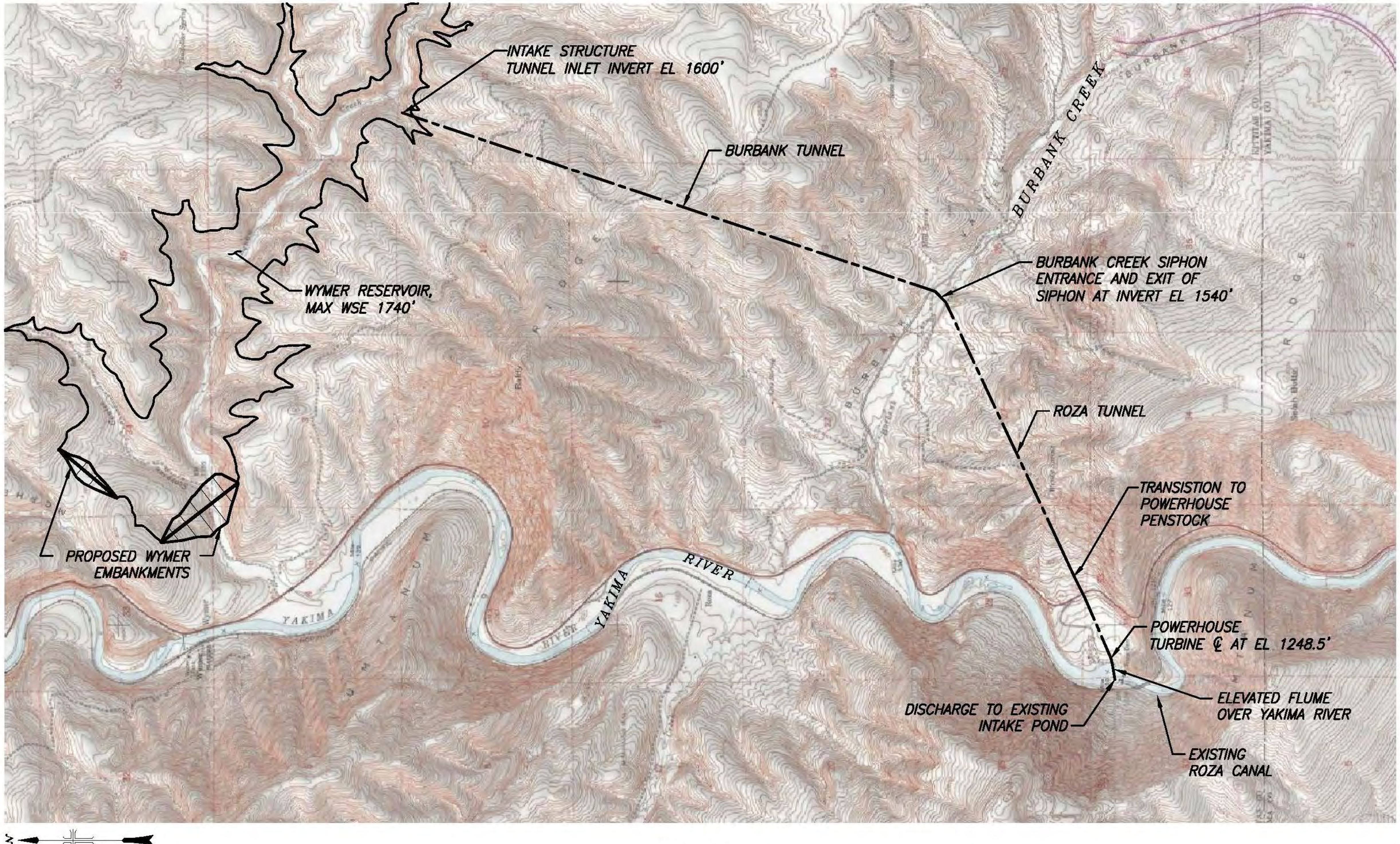
"Yakima River Basin Storage Wymer Dam and Reservoir Appraisal Report," Technical Series No. TS-YSS-16, U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region. September 2007.

"Design of Small Dams," Third Edition, U.S. Department of the Interior, Bureau of Reclamation, Washington DC. 1987.

10.0 List of Preparers

NAME	BACKGROUND	RESPONSIBILITY
HDR Engineering		
Nolan Adams	Staff Engineer	Document Preparation
Leanne Greisen	Staff Engineer	Document Preparation
Blaine Graff	Senior Engineer	QA/QC
Stan Schweissing	Senior Engineer	QA/QC and Coordination

Appendix of Drawings



PLAN

1"=3000'

RECLAMATION
Managing Water in the West

ALWAYS THINK SAFETY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA BASIN STORAGE STUDY PROJECT
WYMER CONVEYANCE – WASHINGTON
FEASIBILITY DRAWINGS
WYMER CONVEYANCE

DESIGNED NBA
DRAWN NBA
CHECKED S. SCHWEISSING
TECH. APPR. NAME – TITLE
APPROVED ADMINISTRATIVE APPROVAL – NAME – TITLE

ISSAQUAH, WA 02.15.2011

Wymer Conveyance Design
Site Map

01

SHEET 1 OF 11

DATE AND TIME PLOTTED
Feburary 15, 2010 16:00
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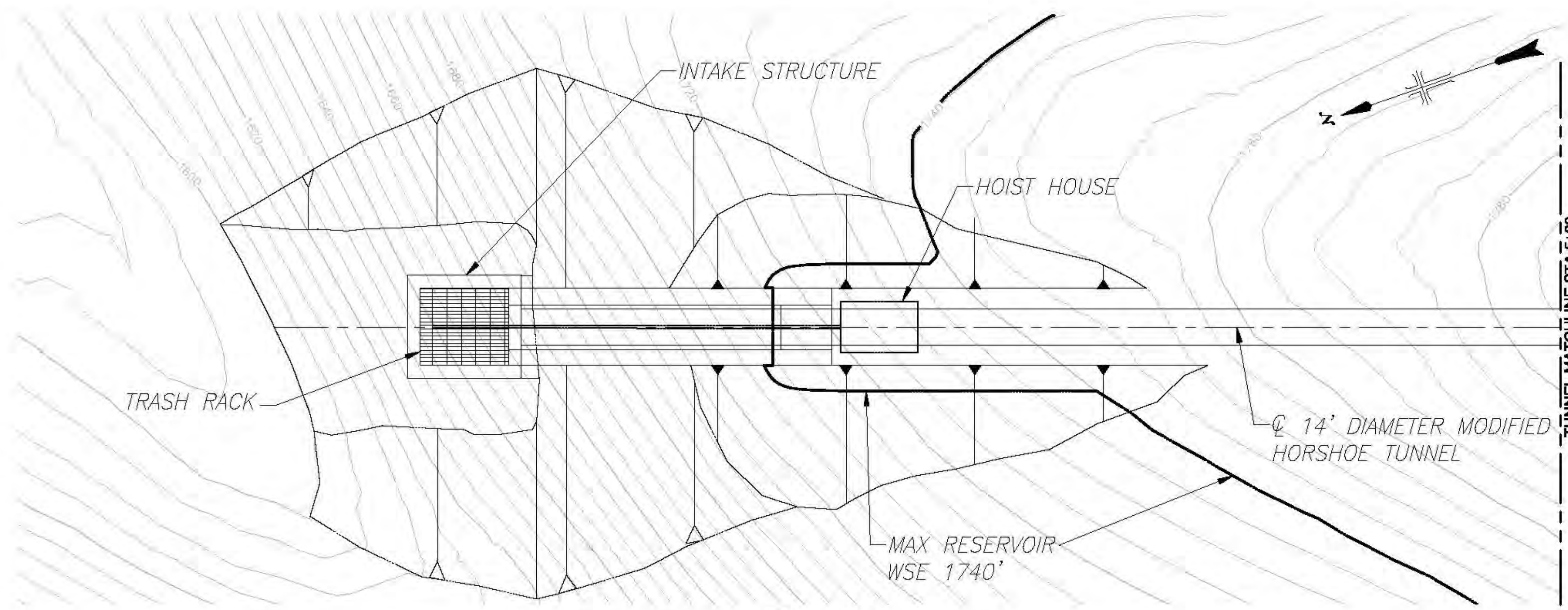

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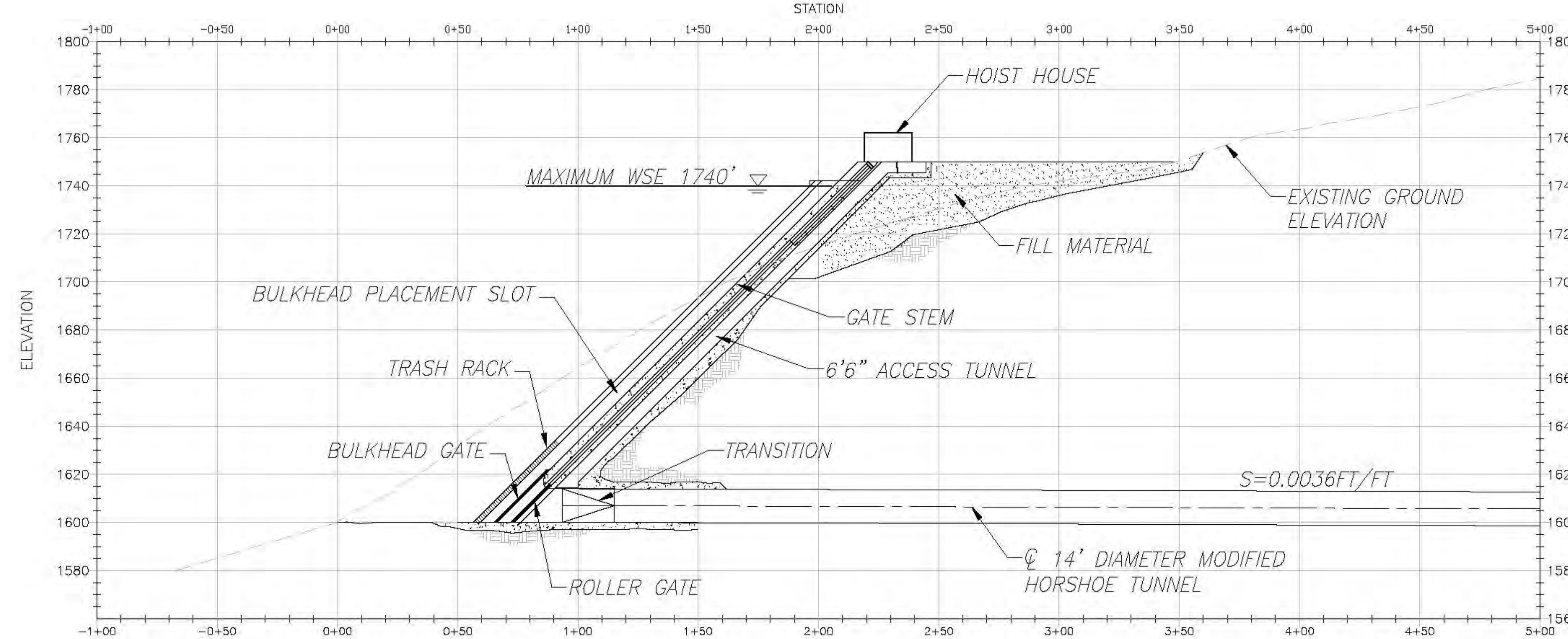

PROFILE

1"=60'

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FEASIBILITY DRAWINGS
WYMER CONVEYANCE

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DRAWN N. ADAMS
CHECKED S. SCHWEISSING
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ISSAQUAH, WA 2.15.2011

Intake Structure
Plan and Section
Sta. 0+00 to 5+00

02

SHEET 2 OF 11

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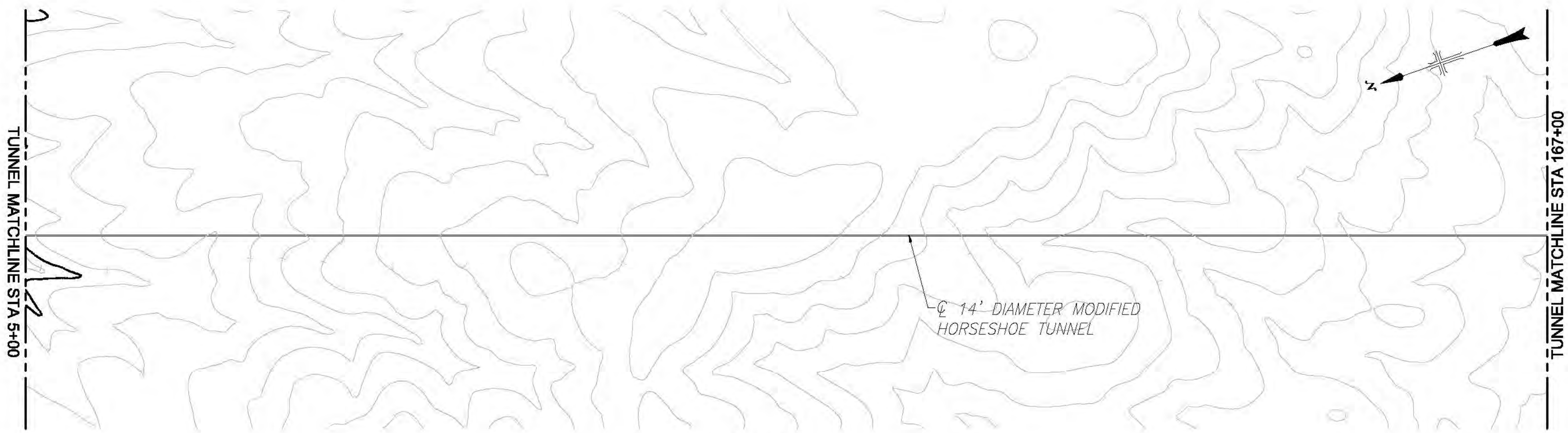

PLAN

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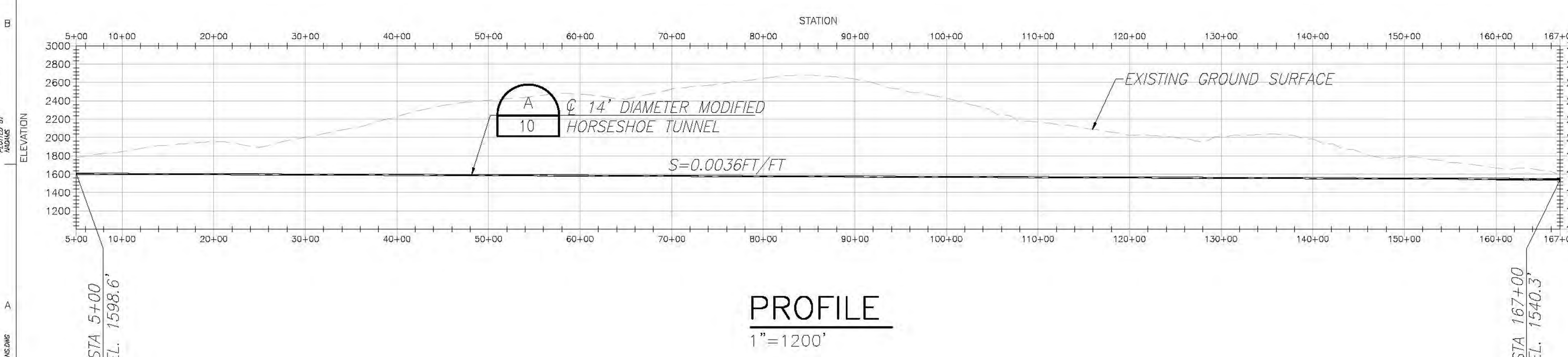

PROFILE

1"=1200'

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WYMER CONVEYANCE

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DRAWN N. ADAMS
CHECKED S. SCHWEISSING
TECH. APPR.
APPROVED
ISSAQUAH, WA 02.15.2011

Burbank Tunnel
Plan and Profile
Sta. 5+00 to 167+00

03

SHEET 3 OF 11

DATE AND TIME PLOTTED February 15, 2011 16:00
PLOTTED BY ADAMS

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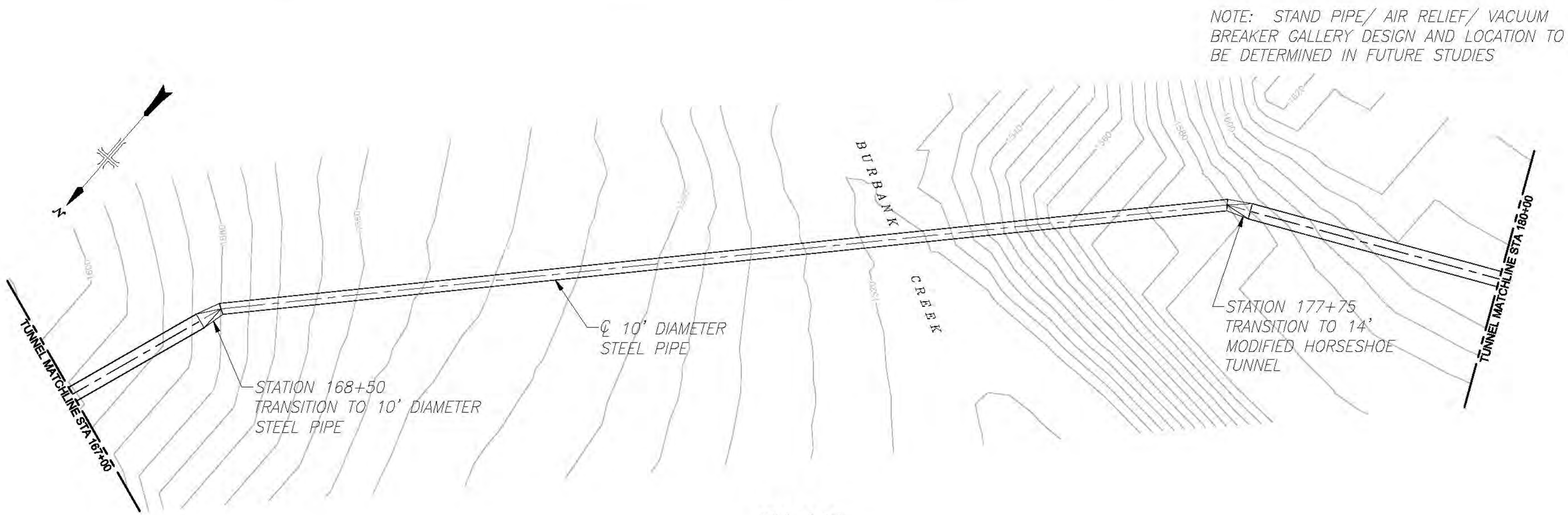
CAD FILENAME WYMER FEASIBILITY DRAWINGS.DWG



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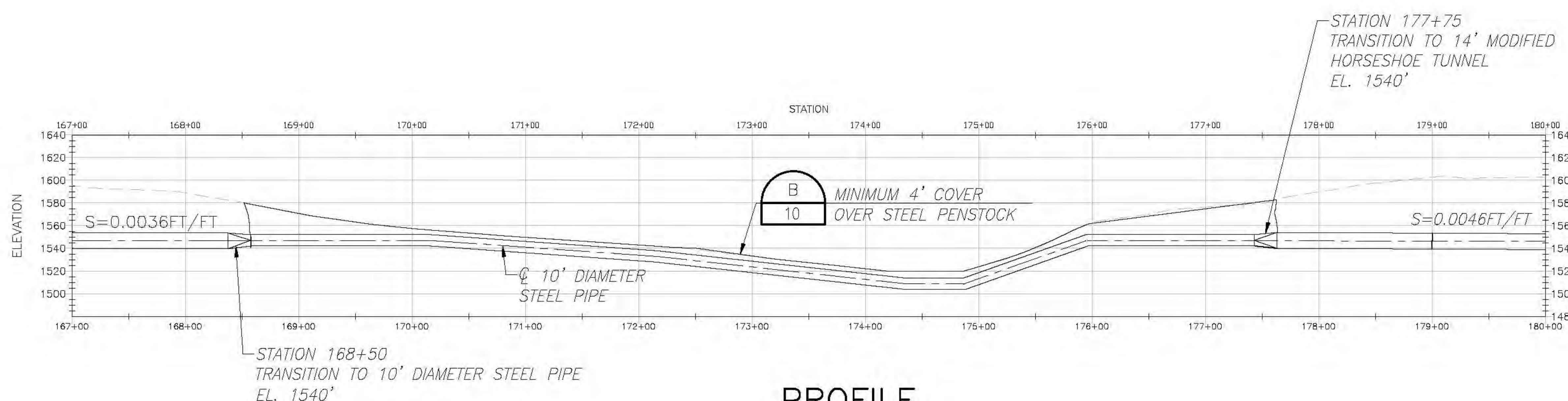

PROFILE
1"=100'

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WYMER CONVEYANCE

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Burbank Creek Siphon
Plan and Profile
Sta. 167+00 to 180+00

04
SHEET 4 OF 11

DATE AND TIME PLOTTED February 15, 2011 16:00
PLOTTED BY NADAMS

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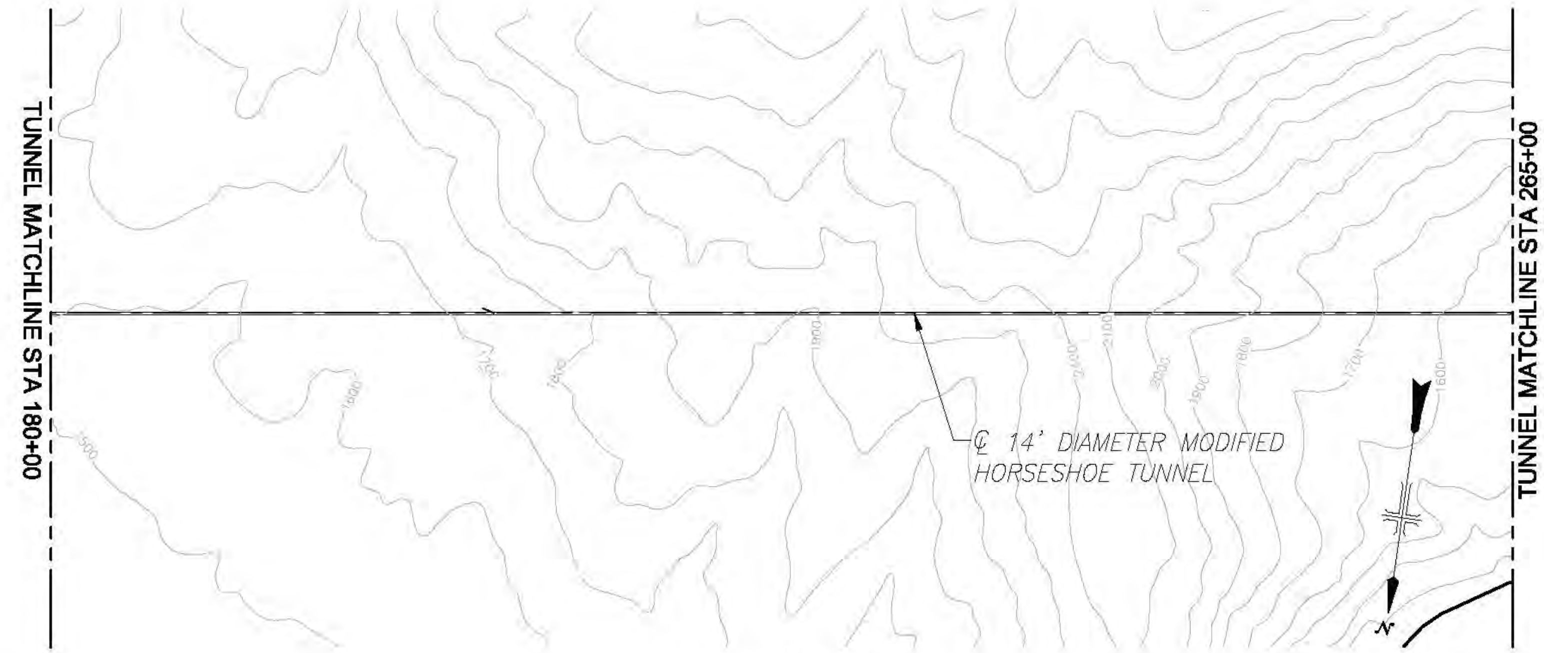

PLAN
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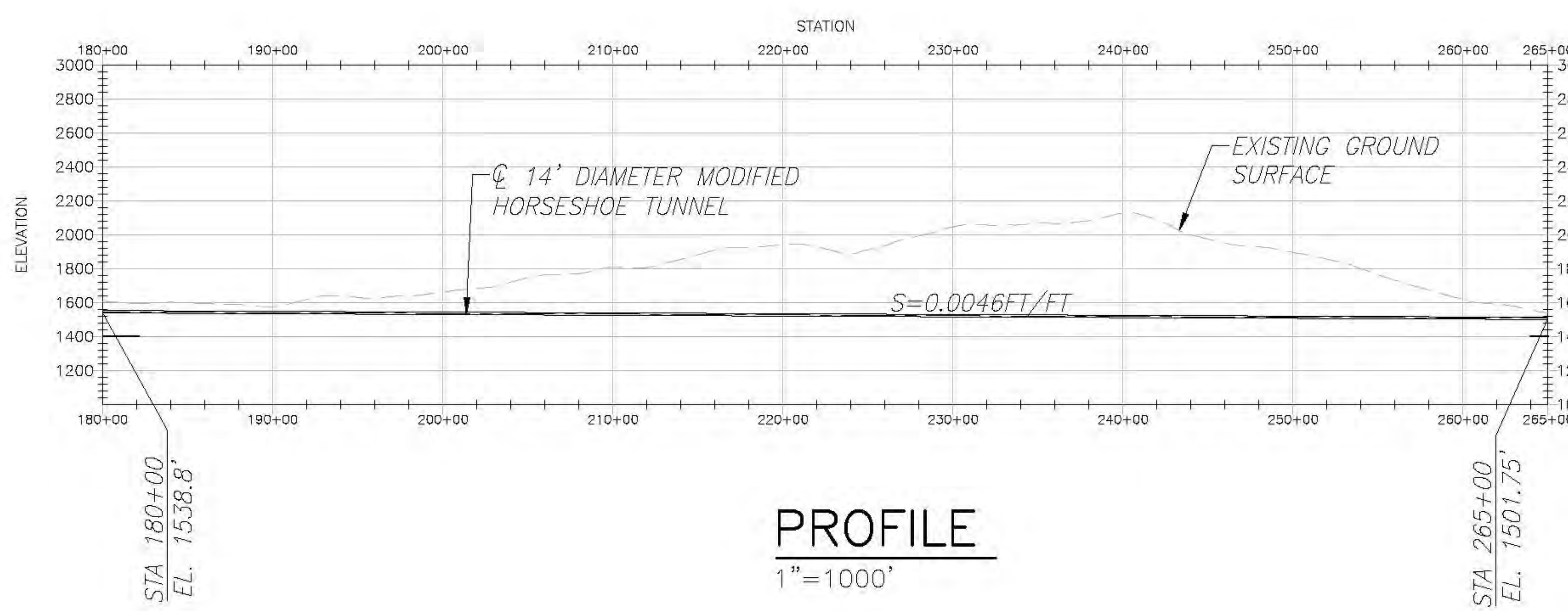

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CAD FILENAME WYMER FEASIBILITY DRAWINGS.DWG

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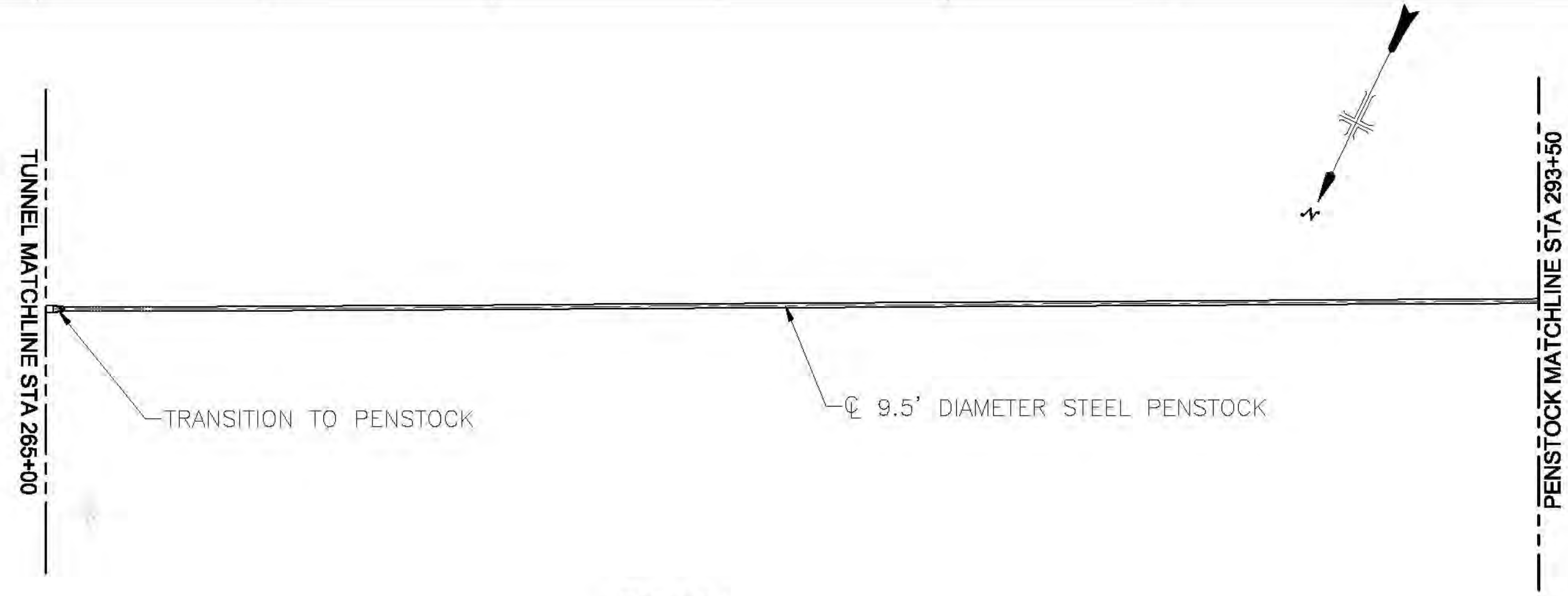
Roza Tunnel
Plan and Profile
Sta. 180+00 to 265+00

05
SHEET 5 OF 11



PLAN
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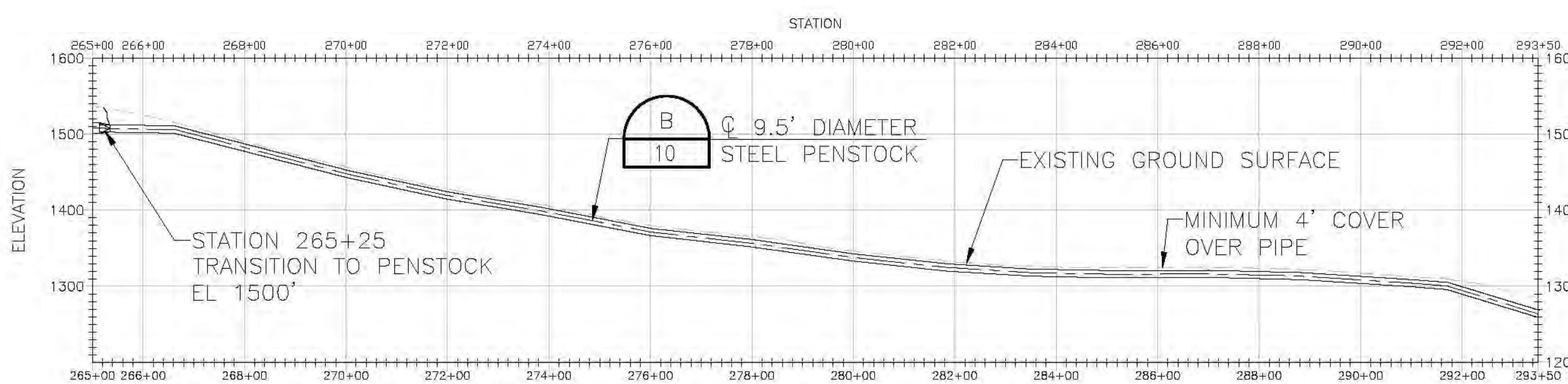

PROFILE
1"=300'

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Penstock
Plan and Profile
Sta. 265+00 to 293+50

06
SHEET 6 OF 11

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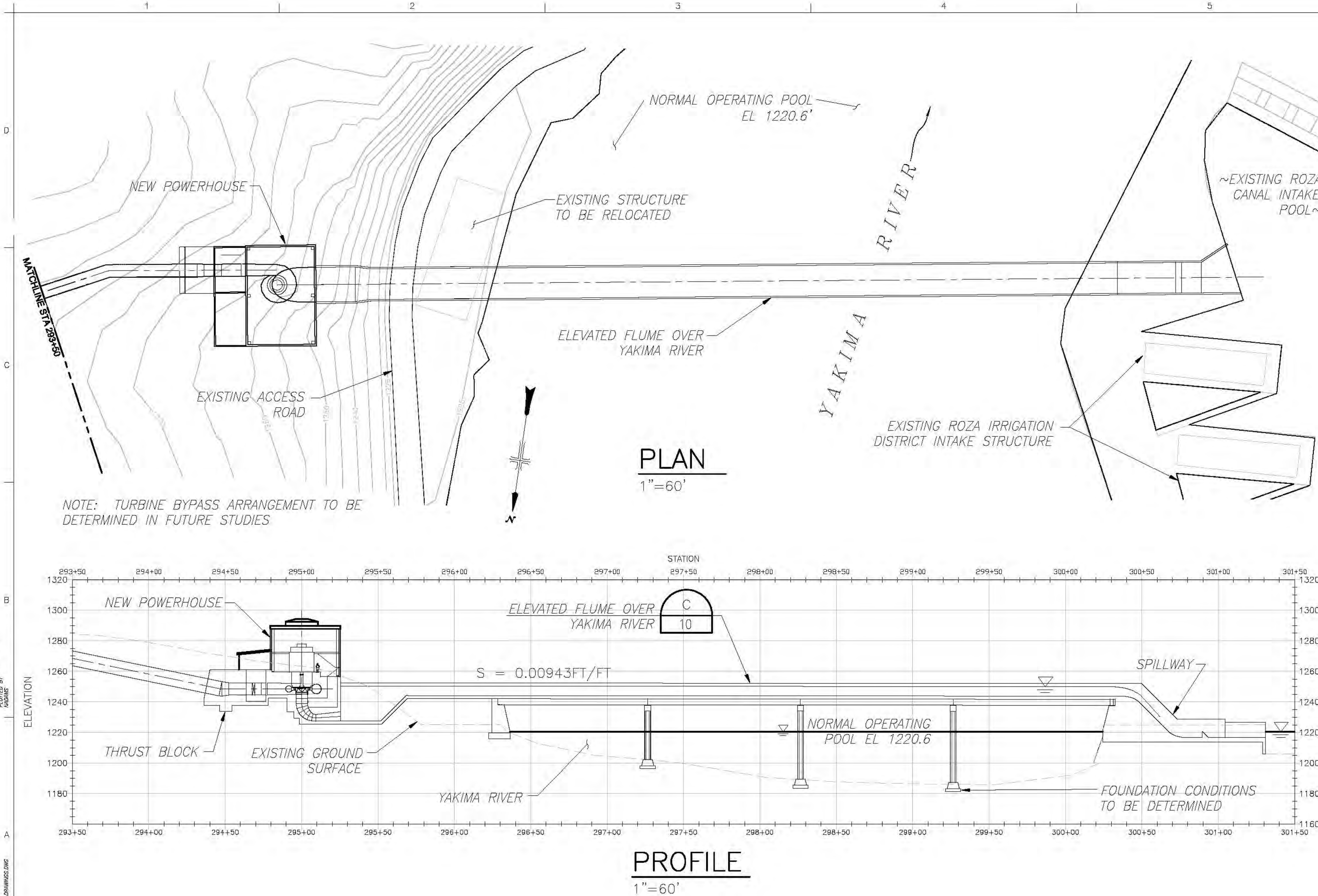

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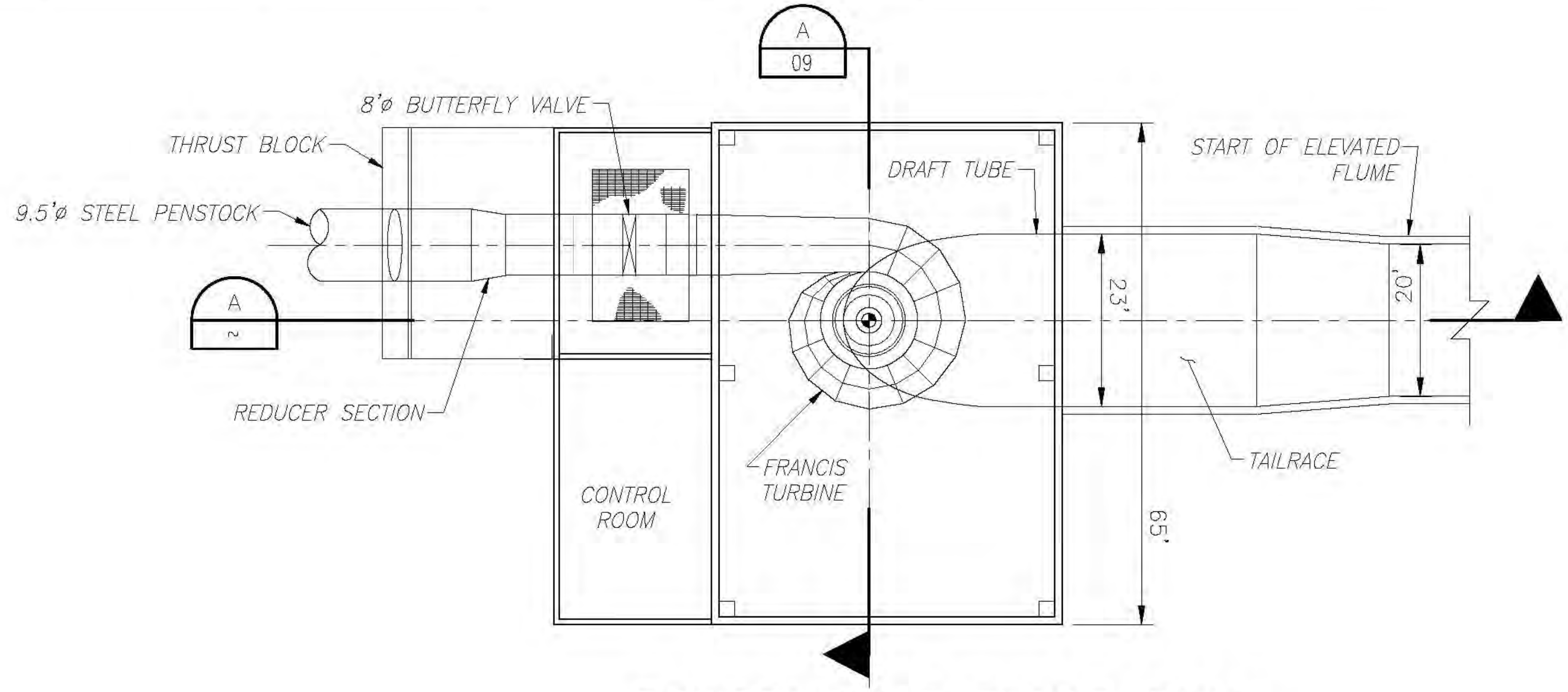
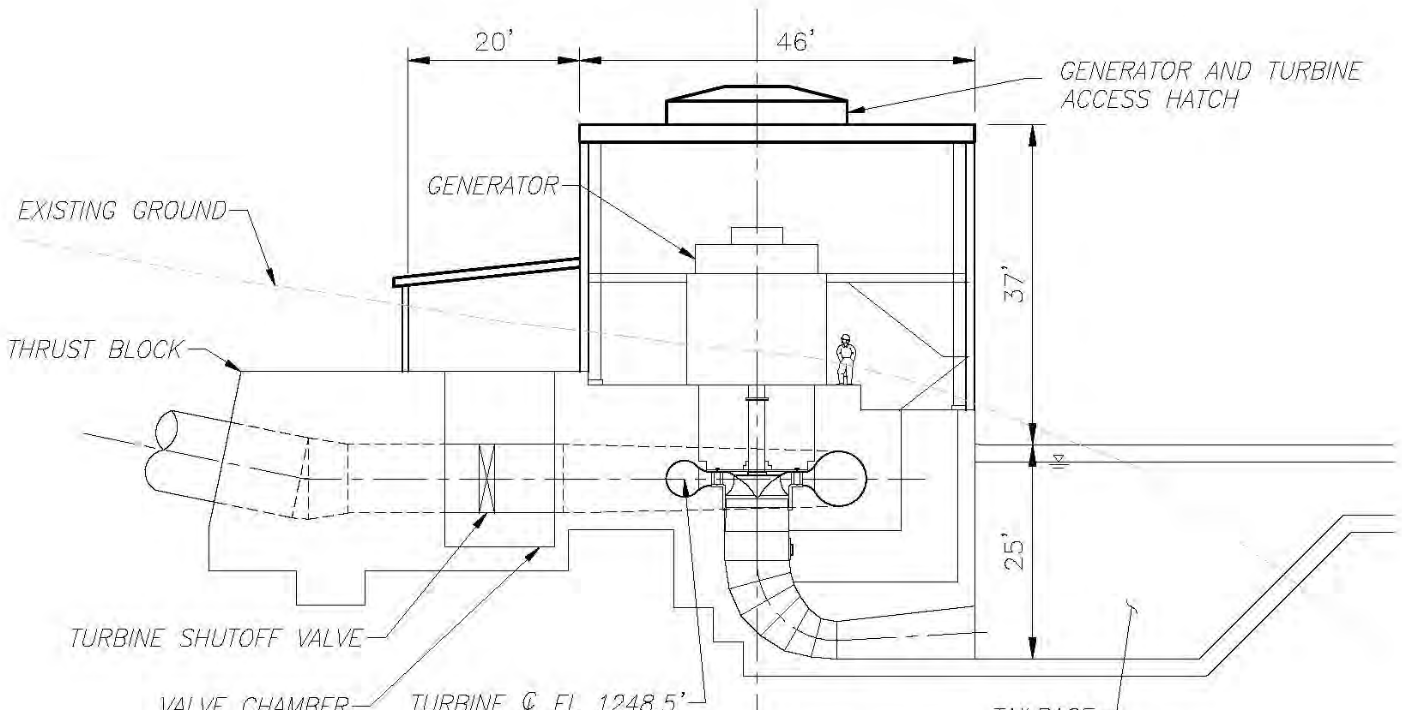
Powerhouse and Flume
Plan and Profile
Sta. 293+50 to 301+50

007
SHEET 7 OF 11



POWERHOUSE FLOOR PLAN

1"=20'



POWERHOUSE SECTION

A
~

1"=20'

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Powerhouse
Plan and Section

08

SHEET 8 OF 11

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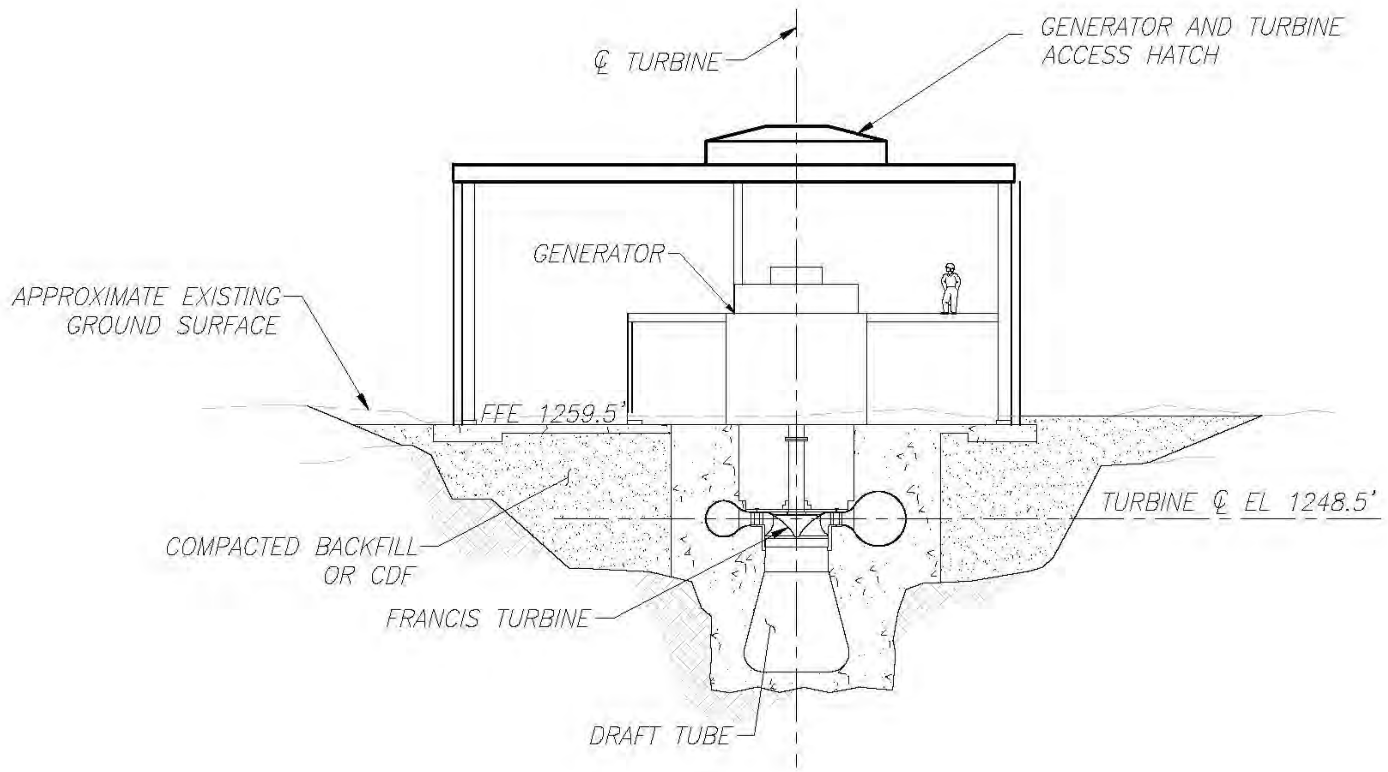

POWERHOUSE SECTION

1"=10'

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Powerhouse Section

09

SHEET 9 OF 11

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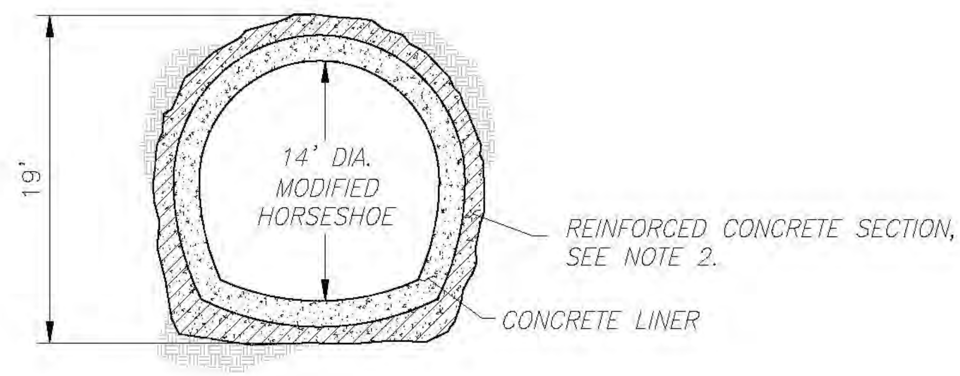
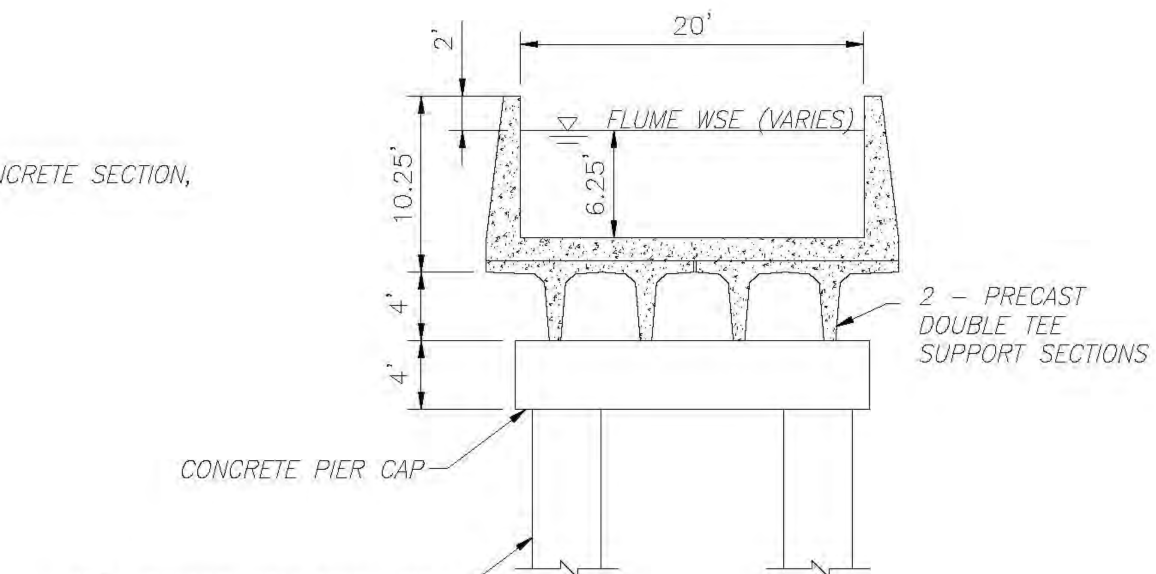
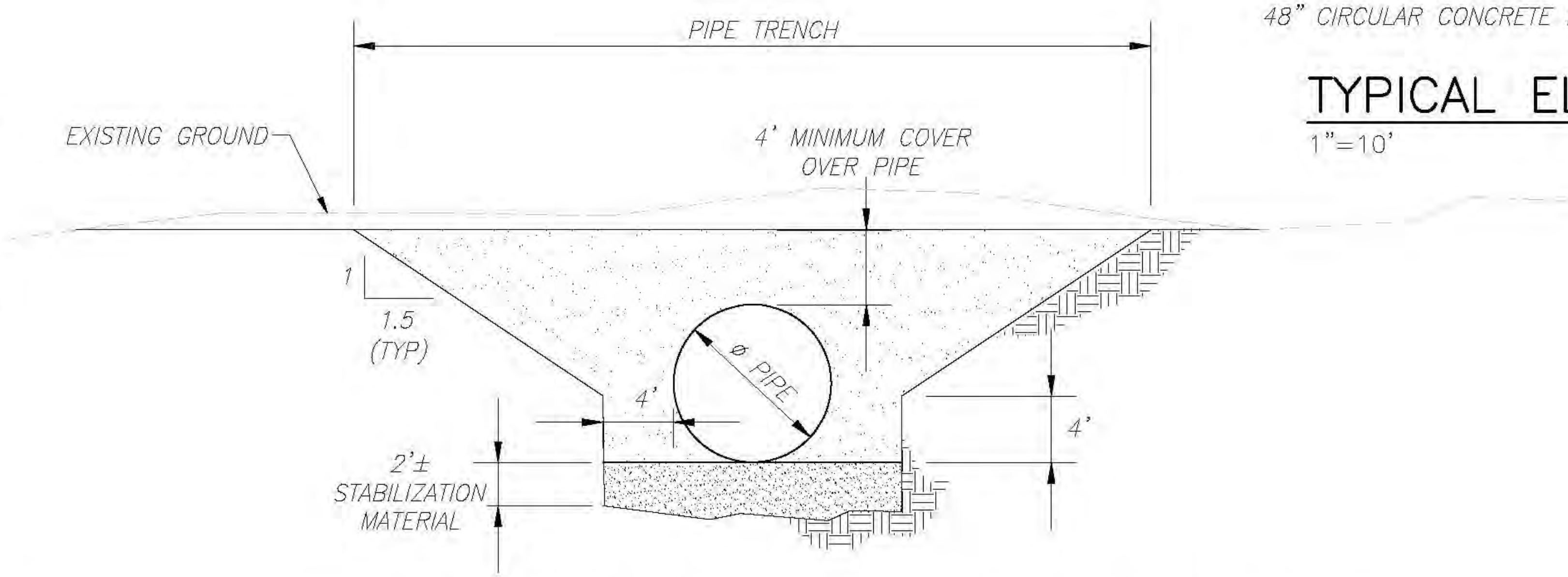


TYPICAL TUNNEL SECTION
1"=10'



TYPICAL ELEVATED FLUME SECTION
1"=10'



TYPICAL BURIED PENSTOCK SECTION
1"=10'

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Wymer Conveyance
Typical Sections

10
SHEET 10 OF 11

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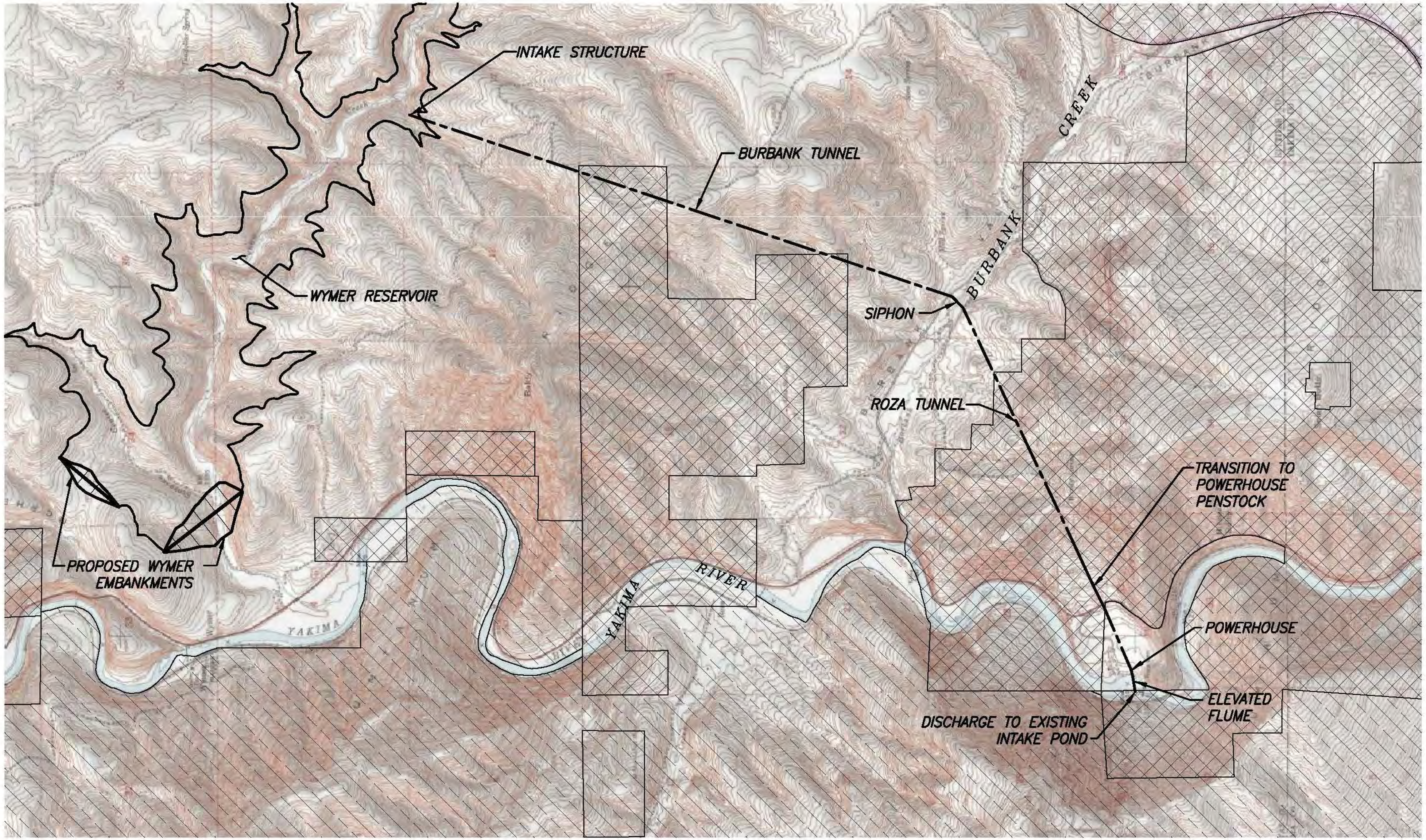

PLAN

1"=3000'

(cross-hatch)	US GOVERNMENT
(single hatch)	STATE OF WASHINGTON

NOTE: ALL OTHER LAND IS PRIVATE

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Wymer Conveyance Design
Land Ownership Map

11

SHEET 11 OF 11

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