PHASE 2 REPORT: REFINED ENGINEERING AND COST ESTIMATE FOR SWITZLER RESERVOIR

WRIA 31 HORSE HEAVEN WATER STORAGE APPRAISAL ASSESSMENT

Prepared for: WRIA 31 Planning and Advisory Committee

Project No. 090045-009-02 • December 26, 2012
Funded by Ecology Grant No. G1100215
Ecology Pub.# 17-12-008

Prepared in collaboration with ANCHOR QEA

Aspect CONSULTING

DEPARTMENT OF ECOLOGY State of Washington

earth + water

To request ADA accommodation for disabilities, call Ecology at 509-454-4335 or visit http://www.ecy.wa.gov/accessibility.html. Persons with impaired hearing may call Washington Relay Service at 711. Persons with speech disability may call TTY at 877-833-6341.

Aspect CONSULTING

PHASE 2 REPORT: REFINED ENGINEERING AND COST ESTIMATE FOR SWITZLER RESERVOIR

WRIA 31 HORSE HEAVEN WATER STORAGE APPRAISAL ASSESSMENT

Prepared for: WRIA 31 Planning and Advisory Committee

Project No. 090045-009-02 • December 26, 2012

Aspect Consulting, LLC

J. RYAN BROWNLEE STATE OF WASHINGTON 44411 REGISTERED PROFESSIONAL ENGINEER

12/21/12

Ryan Brownlee, PE
Senior Water Resources Engineer
rbrownlee@aspectconsulting.com

Steve Germiat, LHG
Senior Associate Hydrogeologist
sgermiat@aspectconsulting.com

W:\090045 WRIA 31 Phase 4\Deliverables\Phase 2 Report\HHH_Appraisal Study_Phase II_Repor.doc

Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

This report presents Phase II of the WRIA 31 Horse Heaven Water Storage Appraisal Assessment, which includes a refined engineering evaluation and cost estimate for a surface reservoir in Switzler Canyon (Switzler Reservoir). This report also presents a cost-based assessment of water allocation alternatives to assist with future planning for use of the stored water, should the reservoir proceed into design phases.

The initial Horse Heaven Water Storage Pre-Feasibility Study (Aspect and Anchor QEA, 2010) presented a high-level preliminary assessment of numerous surface reservoir sites, and arrived at a preferred storage alternative that included two surface reservoirs—Alder Reservoir and Switzler Reservoir—and aquifer storage and recovery (ASR) in the western Horse Heaven area. In Phase I of the appraisal assessment, Alder Reservoir was determined to be fatally flawed due to landslide hazards (Aspect and Anchor QEA, 2012). The 2010 pre-feasibility study included a preliminary estimate of project costs for the Switzler Reservoir. This appraisal-level assessment presents a more refined engineering evaluation of improvements required for construction of Switzler Reservoir with corresponding updated cost estimates. Additionally, this report includes a preliminary evaluation of water availability and operational water balance, and a discussion of the anticipated permitting process for the proposed Switzler Reservoir.

This second phase of the appraisal assessment concludes that a new Columbia River off-channel storage reservoir could be constructed in Switzler Canyon, with a peak storage capacity of approximately 44,000 acre-feet, through construction of a concrete-faced rockfill dam approximately 325 feet in height. Water would be delivered to the reservoir from the Columbia River during periods when water is available (regulatory instream flow minimums are met), which is limited during dry water years and some months of average years. Water would be released from the reservoir as mitigated supply for new water demand when water is not available in the Columbia River to meet the demand. The maximum new mitigated supply that could be made available by the project was estimated assuming that at least 75% of the annual supply would be available with 100% reliability and that the total annual supply would be available with 90% reliability (9 out of 10 years). If a 200-cubic-feet per second (cfs) pump station is constructed to fill the proposed reservoir, it is estimated that approximately 41,000 acre-feet of new mitigated supply could be developed and supplied by the project with 91% reliability. In 9% of years, newly generated mitigated supply would be limited; however, the project would supply to 31,000 acre-feet (75% of supply) with 100% reliability. In wet years, the full reservoir capacity of 44,000 acre-feet could be stored and used for supply.

At this appraisal phase of the project, it is estimated that the Switzler Reservoir project would include the follow major construction elements:

- A 200-cfs pump station on the Columbia River adjacent to the existing agricultural pump station at the mouth of Switzler Canyon;
- A 325-foot tall rockfill dam to create a 44,000 acre-foot storage reservoir;

- An emergency side-channel spillway and common inlet/outlet works at the proposed dam;
- A low-level outlet to Switzler Canyon at the downstream toe of the dam;
- 5,800 linear feet of 84-inch diameter, welded-steel inlet/outlet pipeline;
- An 84-inch diameter outfall to discharge reservoir water to the Columbia River; and
- Improvements to the Switzler Canyon stream channel downstream of the reservoir to improve conveyance conditions, reduce erosion potential, and mitigate for aquatic habitat impacts.

Additional improvements would also be undertaken to mitigate for environmental impacts.

At this appraisal phase of assessment, the capital cost estimate for the project, including Washington State sales tax, contingencies, and indirect costs, is $281 million, which equates to a cost of $13 million or $318 per acre-foot when amortized annually. Annual operations and maintenance (O&M) costs are estimated at $4.5 million or $109 per acre-foot. Total cost per acre foot for new mitigated water supply from Switzler Reservoir is therefore estimated at $427 per acre-foot. Based upon the preliminary benefit-cost analysis, these costs may be justifiable for funding through State, Federal or local sources, including local match requirements.

The proposed reservoir will require the acquisition of various permits from local, State and Federal agencies, including a full suite of aquatic permits pursuant to the Clean Water Act and Endangered Species Act (ESA). The project will require State Environmental Policy Act (SEPA) review and National Environmental Policy Act (NEPA) review if Federal funding is involved. Based upon the preliminary assessments of this project, there are no known existing conditions that would prevent obtaining necessary permits, provided adequate mitigation measures are implemented as a component of the project.

Central to the permitting strategy will be the preparation of a NEPA/SEPA environmental impact statement (EIS) which will address most of the specific permitting requirements for this project. The next step for the project would include securing funding for NEPA/SEPA review, during which time further definition of the project and further community involvement would occur. It is anticipated that the project environmental review and permitting for this project would likely take up to 3.5 years to complete, with subsequent design and construction requiring approximately 5 years.

1 Introduction

1.1 Previous Horse Heaven Water Storage Studies

1.1.1 Appraisal Assessment, Phase I

In accordance with Ecology grant number G1100215, the water storage appraisal assessment was conducted in two phases. Phase I focused on identifying potential fatal flaws associated with two surface reservoir alternatives: Alder Reservoir and Switzler Reservoir. The fatal flaw assessment included evaluation of geologic stability, channel geomorphology, aquatic habitat, terrestrial habitat, and archaeological resources. That report (Aspect and Anchor QEA, 2012) concluded that the Alder Reservoir is fatally flawed due to landslide hazards. The Switzler Reservoir alternative was found to be not fatally flawed; therefore, it was selected to move forward to Phase II (refined engineering assumptions and cost estimating).

1.1.2 Initial Benefit – Cost Assessment for Water Allocation Options

Aspect completed an initial evaluation of estimated costs and economic benefits under a range of potential scenarios for allocating new water supply from the proposed Switzler Reservoir. The economic evaluation was presented via a technical memo dated August 20, 2012, and was presented to the WRIA 31 Planning and Advisory Committee (Advisory Committee) for review and discussion in an August 2012 meeting. The evaluation has been subsequently revised based upon the updated opinion of probable costs herein. The updated Initial Benefit-Cost Assessment for Water Allocation Options is included in Appendix A. The following summarizes the key findings of the economic evaluation.

The economic evaluation applied two different methods commonly employed by public agencies, including the Department of Ecology's Office of Columbia River (OCR) and Washington State University. The evaluation calculated expected levels of regional benefits (e.g., jobs/increased tax revenue) that would accrue if the water were allocated to various beneficiaries, including new agriculture, new municipal supply, reducing drought risk of interruptible water users, or benefiting instream flows. The evaluation showed multiple ways for water to be allocated to beneficiaries and achieve a positive benefit-cost ratio, which would be necessary for a storage project to be viable. Although the two methods produced differing results, the largest gains accrued from apportioning water to new agriculture and new municipal uses. Drought relief for interruptible water rights produced lesser benefits because the benefit is a function of drought frequency (no positive benefit in non-drought years). Instream flow benefits this low in the Columbia River system produced a relatively low economic benefit, but depending on the source of funding for the reservoir, would likely be a required component.

Although there were several allocation alternatives that indicated the entire capital cost of the project could arguably be publically (grant) funded based on the strength of the regional benefit, annual operational costs were viewed as the minimum requirement contributed by local match (the beneficiaries themselves). The previously estimated annual operation and maintenance (O&M) cost was $157/acre-foot (Aspect and Anchor QEA, 2010). Costs to individual farmers located remote from Switzler Reservoir could approach twice that cost, since they would have to pump from the Columbia River and those costs would be in addition to river operations. The majority of water made available by this project would be sourced from the Columbia River rather than directly from the reservoir itself. Therefore, O&M costs associated with this project would not cover the total cost associated with water delivery to the final place of use. That is, water would be effectively pumped twice: once to the reservoir (and subsequently released back to the Columbia River) and once to the place of use. Hence, O&M costs expected to be borne by water users could approach roughly double those costs presented here.

During the August 2012 meeting, Advisory Committee members provided feedback that, while significant, these costs could likely be born depending on crop type selected by the farmer. During subsequent NEPA/SEPA scoping for this project, additional input regarding the effect of annual O&M costs on crop type and farmer access (affordability) will be obtained to refine this evaluation.

1.2 Appraisal Study – Phase II

The intent of this second phase of the water storage appraisal assessment is to develop refined engineering assumptions and opinion of probable costs for the proposed Switzler Reservoir. This study was prepared for use by project stakeholders in order to guide decisions regarding the viability of this project as a future water supply source.

This study was developed based upon readily available existing information and stops short of performing a detailed feasibility assessment, which would be completed in further project development stages. A future feasibility study supporting project design would include extensive subsurface explorations, geotechnical evaluation, detailed land ownership and right-of-way investigations and discussion, detailed hydrologic evaluations including streamflow measurement and monitoring within Switzler Canyon, environmental investigations and inventory including wetland delineations and analysis of instream resources, etc. A future feasibility study would also include detailed topographic survey, preliminary engineering and further refinement of costs, as well as a detailed economics benefit-cost analysis.

1.2.1 Phase II Approach

Phase II involves a coarse-scale evaluation of project details including water availability, existing site conditions, anticipated infrastructure including embankment dam location and composition, embankment appurtenances such as inlet/outlet works, spillway, water supply, etc. Environmental mitigation including wetlands and shoreline are also considered and anticipated permitting is discussed. A refined opinion of probable project costs is then developed. Based upon refined cost estimates, project economics generated were updated and are presented as Appendix A.

1.2.2 Report Organization

This rest of this report is organized as follows:

- **Section 2 Project Background –** Provides an overview of the project setting and geology, site hydrology, and statement of storage goals and general project criteria.

- **Section 3 Operational Evaluation and Water Balance –** Presents water operations (water balance) over wet / dry years (existing and future) considering water availability (Columbia River BiOp and Instream Flow).
- **Section 4 Refined Engineering Assumptions –** Discusses major necessary improvements for the reservoir including identification of potential material sources, embankment configuration and operational appurtenances, water supply and conveyance infrastructure, and environmental mitigation improvements.
- **Section 5 Refined Opinion of Probable Costs -** Provides cost estimating methodology and assumptions related to development of updated opinion of probable costs. Also presents refined opinion of probable project costs for both capital and annual operations and maintenance.
- **Section 6 Permitting Process and Strategy –** Describes anticipated permits necessary for construction and operation of the reservoir, including description of process and timeline.
- **Section 7 Summary and Recommendations –** Summarizes the Phase II appraisal assessment and provides recommendations for further work if the Advisory Committee and Ecology feel the project should proceed.
- **Section 8 References –** Lists references for text citations.

2 Project Background

2.1 Project Objective and Criteria

The intent of the Horse Heaven water storage project is to create seasonal water storage in the Horse Heaven region of WRIA 31 that could be used for multipurpose benefits. The Switzler Reservoir alternative has the potential for development of approximately 44,000 acre-feet of storage which could be conveyed to the Columbia River during times of relative water scarcity in order to mitigate for new appropriation of water from the Columbia River. In other words, the project would put water into storage and establish mitigated water rights for Columbia River diversion equal in quantity and timing to the volume of water released.

Elements of the project include the construction of an embankment dam to impound water within Switzler Canyon, piped conveyance between the reservoir and the Columbia River for both pumping into and releasing from storage, a Columbia River pumping station, and environmental mitigation improvements in Switzler Canyon downstream of the dam. Table 2-1 summarizes the basic criteria for the project.

Table 2.1. Basic Project Criteria

Peak Storage Volume (acre-feet)	44,000
Maximum Instantaneous Filling Capacity (cfs)	200
Diversion Period	When Columbia River Water is Available[1]
Maximum Instantaneous Draining Capacity (cfs)	280
Release/Supply Period	April 1 – October 30
Surface Water Source	Columbia River

2.2 Existing Conditions

The Horse Heaven water storage appraisal assessment Phase I Report provides a detailed characterization of existing conditions for Switzler Reservoir (Aspect and Anchor QEA, 2012). The following sections provide an abbreviated general description of existing conditions pertinent to conceptual design of the reservoir and appurtenances including project location, site geology and hydrology. Site photographs of the existing conditions are provided in Appendix C.

2.2.1 Project Location

The proposed reservoir created by the improvements would occupy the majority of Switzler Canyon which is the near the confluence of the Switzler drainage with the Columbia River at approximately Columbia River Mile 302 within the McNary Dam pool (Lake Wallula) in Benton County. This site is situated approximately 16 miles south of Kennewick and 11 miles east of Plymouth, Washington, and Umatilla, Oregon. The area of inundation created by the proposed reservoir would occupy approximate 415 acres, commencing approximately 1.1-miles upstream of the confluence of the Switzler drainage with the Columbia River (Figure 2-1).

2.2.2 Existing Infrastructure

Access Infrastructure

The project is situated within 9 miles of Interstate 82 along improved roads; approximately 7 miles of the 9 miles are paved and 2 miles are gravel. Direct access into Switzler Canyon and the project site is available by a gravel road which enters the canyon from the northwest. This gravel roadway crosses the canyon bottom and traverses the east canyon slope to provide farm-to-market truck transportation servicing the agricultural lands immediately east of the reservoir site. Additional access into the canyon via gravel road exists along the southwestern rim, near the confluence of drainage with the Columbia River. An unimproved dirt road along the canyon floor, east of the natural drainage, also exists. This road has not been maintained by the local landowner and has been used most recently for recreational purposes.

The BNSF railway parallels the Columbia River along the river's northern bank, which crosses Switzler Canyon near its mouth. The nearest serviceable rail spur associated with the BNSF railway is approximately 14 miles west of the site in Plymouth, Washington and is owned by the Washington State Department of Transportation (WSDOT) for use in servicing a gravel aggregate quarry.

[1] Estimated Columbia River water availability under existing conditions is summarized in Table 3-1

Lake Wallula, which is formed by the pool of McNary Dam, is accessible by barge via navigable locks of the Lower Columbia River; however, no barge-receiving docks exist within close proximity to the site.

Agriculture

The area surrounding the proposed reservoir is primarily improved irrigated agriculture lands (both perennial and seasonal crops), which encroach upon the canyon rim to the north, east, and west. Infrastructure typical of irrigated agriculture exists including piped irrigation conveyance, water methods (sprinkler, center pivot, micro-irrigation, etc.), farm service roads, support facilities, and material storage yards.

Pump Stations

Three major irrigation water supply pumping stations exist on the Columbia River within relatively close proximity of the site: Easterday/Berrian, Easterday/Premier (Irogrow), and Easterday/Denhoed (Finley) (refer to Figure 2-1). The Easterday/Berrian and Easterday/Denhoed stations are located approximately 2.1 miles west and 3 miles east, respectively, of the Switzler Canyon drainage, while the Irogrow station is located at the base of Switzler Canyon. Easterday Farms reportedly owns complete interest in both the Easterday/Berrian and Easterday/Denhoed pump stations, and controlling (80%) interest in the Irogrow station. The remaining 20% interest in the Irogrow station is owned by Gilbert Farms. Based upon discussion with Easterday Farms personnel, the pump stations have a combined capacity of approximately 160 cubic feet per second (cfs).

The three river pump stations are reportedly seasonal (not winterized) and have the characteristics shown in Table-2.2.

Table 2.2. Existing Pump Station Information

Pump Station	Approximate Capacity (cfs)	Discharge Pipeline Diameter(s) (inches)
Easterday/Premier (Irogrow)	69	30, 24, 24
Easterday/Denhoed (Finely)	47	36
Easterday/Berrian	44	36

2.2.3 Geology

Regional Geologic Setting

Switzler Canyon lies within the Columbia Plateau, an area of Miocene-age basaltic bedrock composed of many basalt flows, each tens to hundreds of feet thick. Streams and rivers quickly occupied the synclinal low areas on the top of the freshly deposited basalt flows, and sediments accumulated in these low areas before being covered by the next basalt flow. The basalt flows are now separated by rubbly to clayey flow contacts and locally by sedimentary interbeds (collectively termed the Ellensburg Formation) that if present may be up to many tens of feet thick. These basalt flows and their sedimentary interbeds are generally mantled by much younger Pleistocene and Holocene sedimentary and mass-wasting deposits, but are locally exposed at the surface.

The Switzler Reservoir site lies within a tectonically complex area of the Yakima Fold and Thrust Belt containing a series of steep, asymmetric, anticlines and thrust faults separated by broad, gently dipping synclines. The site lies on the gently sloping flank of the Horse Heaven Hills anticline, about 3 miles south of the Columbia Hills anticline, and about 7 miles southwest of the Rattlesnake Ridge anticline. No active faults have been identified within a mile or more of the Switzler Reservoir site.

Site Geology

Geology at the Switzler Reservoir site is dominated by Quaternary soil units that lie above Tertiary basaltic bedrock. The locations and physical properties of the soil and rock materials at the site impact reservoir slope stability, reservoir foundations, groundwater flow and seepage, and potential for use of on-site geologic materials as dam construction materials.

The basalt flows include, from top down, the Pomona and Umatilla Members of the Saddle Mountains Basalt and the Frenchman Springs member of the Wanapum Basalt (Schuster, 1994, and WDGER, 2012). Members may be composed of several distinctive and separate flows. Thicker flows often exhibit well-developed structures and cooling features including columnar jointing and zones of more closely spaced fractures. Flow tops can be thick and rubbly to brecciated, or thin and smooth. The base of the flows is generally broken to rubbly, and may have glassy to clayey zones from deposition into standing water. The structure of the basalt flows and the nature of the internal fractures is a significant factor in the stability of the site, the morphology of the slopes, and the feasibility of use of basalt as embankment fill or armor material.

These sediments present between basalt flows typically consist of clay, silt, and sand and gravel and regionally range from absent to up to several hundred feet thick. In the Switzler Canyon area, logs of water wells (T19N/R6E/S30N and T24N/R6E/S29E) near the site indicate that individual interbeds within the stratigraphic section of concern for dam and reservoir construction and operations are absent or thin and likely do not exceed about 10-feet thick. Where present, these sedimentary interbeds are significant factors in the slope geomorphology and potential slope stability issues associated with the canyon walls. These sedimentary interbeds and the weak rubbly basalt flow tops and bottoms that bound the individual basalt flows also form the major regional water supply aquifers within the region and are potential sources of leakage in reservoir walls and dam foundations.

Site Geologic Units

The geologic units at the site are presented from generally younger to older. Some of the surficial soil units presented below are not shown on regional maps due to the scale of those maps, but were identified during geologic reconnaissance studies and are relevant to the project. The site geologic units include the following:

- Loess – Composed of windblown silt and fine sand. Loess is mapped throughout much of the uplands outside of the Switzler Canyon area, and the surficial soils that support agriculture in the area. Some areas of dune sand composed chiefly of fine sand with silt, were observed on the upper sections of the canyon walls and rims. Due to similar material properties, the loess and dune deposits are combined and identified here as Loess. This Loess unit is estimated to range from several feet thick to about 30 feet thick where incised by gullies near the rim of the canyon. Loess, or colluvium derived from loess also mantles most older soil and rock units within the canyon.

- Recent Alluvium – Composed of water-worked sand and silt with minor gravel within the channel bottoms. Recent Alluvium occurs within the canyon bottom and meandering channel and floodplains of Switzler Canyon and its larger tributary forks including the east and west forks.
- Colluvium – Colluvium is mixed rock and soil that is being transported slowly down slopes by gravity. Colluvium in much of the Switzler Canyon area is composed of loess mixed with other slope wash materials. Colluvium mantles most or all of the steep slopes except where bedrock is exposed and it usually occurs as a layer several feet thick over undisturbed deposits.
- Talus – Composed of angular rock fragments that have weathered and fallen from outcrops and have accumulated on the slope below. Talus is exposed in isolated areas below basalt cliffs and outcrops.
- Landslide Deposits – Composed of rock and/or soil material transported downslope by mass wasting and landslide processes. Slope morphology indicative of landslide has been identified during the geologic reconnaissance at six locations within the reservoir area, although only one area of landslide debris is indicated within the reservoir footprint on the regional geologic map.
- Outburst Flood Deposits – Composed of sand and gravel where Pleistocene glacial outburst floods from glacial Lake Missoula deposited sand to boulder size sediment. These coarse-grained facies are called the Pasco Gravel. Basalt-rich sand and gravel strata similar in nature to Pasco Gravel are exposed below surficial loess and colluvial deposits in several steep recently eroded gullies on the western canyon slope. The Pasco Gravel or colluvium derived from Pasco Gravel likely occurs elsewhere beneath colluvium and loess and above the basalt within the canyon area.
- Umatilla Basalt – This member of the Saddle Mountains Basalt is the upper flow that is prevalent throughout the Switzler Reservoir area. Umatilla Basalt is noted on the regional geologic maps (Schuster, 1994; WDGER, 2012) to be the uppermost basalt unit exposed within the canyon section, and to be several hundred feet thick with its bottom near elevation 600 feet. Analysis of nearby water supply well logs (T19N/R6E/S30N and T24N/R6E/S29E) indicate the Umatilla Basalt is composed of several flows, each up to about 100-feet thick. Where not covered in colluvium or talus, it occurs as linear cliffs and ledges in canyon north of the confluence of the east and west forks, and generally above about elevation 600 feet in the lower reaches of the canyon.
- Mabton Interbed – A sedimentary unit is noted between basalt layers in a nearby water well log (T19N/R6E/S30N) at about 190- to 198-foot depth. It is noted to consist primarily of fractured basalt, clay, and ash. Stratigraphic analysis suggests that this sedimentary unit is the Mabton Interbed of the Ellensburg Formation. The fractured basalt and sedimentary bed descriptions reported in logs of nearby irrigation well are typical of flow contacts with sedimentary deposits. The volcanic origin of much of the clay in the Ellensburg Formation suggests that this clay is expansive and very weak when weathered and wet. Clayey interbeds of this type are typically easily eroded when exposed, and thus do not form surface

exposures in natural outcrops. The weakness of these units is a key control on the formation of ledges and cliffs in flood scoured and eroded basalt.

- Frenchman Springs Basalt – This is the lower bedrock basalt unit exposed in the canyon section. Frenchman Springs Basalt is noted on the regional maps (Schuster, 1994; WDGER, 2012) to occur generally below about elevation 600 feet. On the T19N/R6E/S30N well log it appears to be composed of several flows about 100- to 150-feet thick, with a weathered or rubbly basalt and clayey layer between the flows. Where not covered by colluvium or loess, it occurs at the site as the cliff- and ledge-forming units within the lower half of the canyon stratigraphic section.

Hillslope Geomorphology

Switzler Canyon is generally steep and narrow, and exhibits generally horizontal basalt ledges and cliffy outcrops that appear to represent in-place exposures of basalt. Slopes between the basalt outcrops are generally mantled in loess and colluvium. Colluvium has two general types. One type consists of loose, dry fine sand and silt derived from downslope movement of loess and eolian sand dune or drift deposits that have settled onto the canyon slopes after being blown across the plateau above the canyon. This loess-derived colluvium layer is at least the 3 feet deep where explored with hand tools. The upper 12 to 18 inches was very loose and heavily burrowed by animals.

The other type of colluvium consists of angular basalt rock fragments and/or rounded gravel within a matrix of silt and sand. This colluvium appears to be a mixture of loess, Pasco Gravel, and talus. It was at least 2-feet thick at several locations explored with hand tools.

Several gullies on the right (west) side of the canyon below the dam site expose steeply dipping stratified sand and gravel that appears to be either Pasco Gravel or colluvium derived from Pasco gravel. The sand and gravel stands in vertical cuts but is not cemented and ravels easily when disturbed.

The overall topography and generally regular but sparse nature of the basalt outcrops on the canyon slopes suggests that the basalt that forms the core of the canyon consists of a series of cliffs and ledges that form large, step-like features on the canyon walls. The steps are generally covered with glacial flood deposits (Pasco Gravel) and younger deposits including colluvium, talus, and some landslide debris.

Deep-Seated Landslides

Topography indicative of deep-seated rotational landslides was observed at several locations within Switzler Canyon. One near the upper end of the east fork of the reservoir may be relatively recent judging by the more prominent shape of an apparent toe bulge. Other possible deep-seated landslides, including one near the proposed right dam abutment, appeared to be much older and inactive, if actually landslides. One landslide indicated on the geologic map (on the left bank of the east fork, about ¼ mile upstream of the fork) could not be confirmed as a slide during the site reconnaissance. If it is a slide, it appears to be old and may be inactive.

The majority of the canyon slopes do not appear to have experienced deep-seated slope movement. The degree of weathering and rounding of the remaining suspect deep-seated landslides suggests great age and inactivity for those slides.

Shallow Landslides

Several active and recent surficial translational landslides were observed above the creek bed on the right bank of the west fork of the canyon. These shallow slides were occurring where the meandering creek had eroded the toe of an angle-of-repose fine sand and silt loess and/or colluvium deposit, causing loss of support at the toe. The angle of failure on these deposits was observed to be about 36 degrees.

2.2.4 Hydrology

Figure 2-2 shows the Switzler Canyon drainage basin. The drainage basin was delineated using digital 1:100,000-scale U.S. Geologic Survey (USGS) topographic mapping. The total drainage basin area upstream of the mouth of Switzler Canyon at the McNary Dam Pool is approximately 19,740 acres (30.8 square miles). The drainage basin ranges in elevation from more than 1,860 feet (NGVD 29) at the crest of the Horse Heaven Hills to 340 feet (NGVD 29) at the McNary Dam Pool on the Columbia River. The reservoir watershed area upstream of the proposed dam is approximately 19,220 acres (30.0 square miles). The elevation at the location of the proposed dam is approximately 480 feet (NGVD 29).

The mean annual precipitation measured at McNary Dam, approximately 9 miles west of the mouth of Switzler Canyon, is 7.8 inches. The mean annual precipitation measured at Kennewick, approximately 16 miles northwest of the proposed reservoir, is 9.2 inches. There is no precipitation data recorded for the Switzler Canyon drainage basin. Based on data available at nearby stations and the local topography, the mean annual precipitation in the drainage basin is likely in the range of 9 to 10 inches.

The natural hydrologic conditions in Switzler Canyon are likely typical of other nearby intermittent tributaries to the Columbia River. Natural runoff likely occurs intermittently as a result of precipitation events; however, field observations indicate that the existing hydrology is likely influenced by irrigation return flows from adjacent agriculture activities upslope of Switzler Canyon. Two site visits have been made to observe conditions in Switzler Canyon:

- The first was made to observe conditions for preparation of the *Phase I Report: Horse Heaven Water Storage Appraisal Assessment* (Aspect and Anchor QEA, 2012) in late September 2011; and
- The second was made during the preparation of this report on November 6, 2012.

Flow was observed in lower Switzler Canyon and in the west fork of Switzler Canyon during these site visits. Neither site visit followed a precipitation event that would have contributed to the flows observed in Switzler Canyon. Irrigated agriculture was observed upslope of Switzler Canyon during both site visits.

No flow measurement data is available for Switzler Canyon. Flows observed in lower Switzler Canyon during the site visits were visually estimated to be less than 10 cfs. Observations made during the site visits suggest that high-flow events occur. The property owner’s operations staff indicated that a flood event in spring 2011 buried their river pump station intake in sediment. Evidence of that event was observed in the form of large sediment deposits and erosion in the channel in lower Switzler Canyon.

Successful implementation of the proposed Switzler Reservoir will require a detailed analysis of peak flows including the 100-year flood and the probable maximum flood (PMF). Additional information and a preliminary estimate of peak flow rates are included in Section 4.2.3.

3 Operational Evaluation and Water Balance

A preliminary operational evaluation of the proposed Switzler Reservoir was completed to assess the following:

- Reservoir filling and release rates for sizing pump station and reservoir inlet/outlet facilities; and
- The additional annual demand the proposed project would potentially be able to supply.

This section presents the following: a summary of operational constraints and assumptions used in the preliminary evaluation, a description of the spreadsheet model developed to evaluate reservoir operations, a summary of the results of the evaluation, and an overall summary of operations and additional supply that could be made available by the proposed project.

3.1 Operational Constraints and Assumptions

Switzler Reservoir operations will be constrained by the amount of water seasonally available in the Columbia River for both existing and future conditions, the magnitude and seasonal variation of demands supplied by the project, reservoir capacity, and the capacity of pumping and reservoir inlet/outlet facilities.

3.1.1 Columbia River Water Availability

Existing Conditions

Columbia River water availability for existing conditions was estimated using flows obtained from the Bonneville Power Administration (BPA) HydSim model for the Columbia River, from the *Federal Columbia River Power System 2010 Supplemental Biological Opinion* (2010 BiOp) flow targets (NMFS, 2010), and from minimum instream flows set by Chapter 173-563 WAC. The HydSim model uses Columbia River hydrology from water years 1929 to 1998 and accounts for current hydropower system operations. The 2010 Federal BiOp flows or State minimum required instream flows for the three Columbia River dams that have 2010 BiOp flow requirements currently in place (Priest Rapids, McNary, and Bonneville) were subtracted from modeled outflows at those dams to estimate the amount of water available for pumping under existing conditions. Table 3-1 summarizes the estimated Columbia River water availability for existing conditions.

Table 3-1. Estimated Columbia River Water Availability – Existing Conditions

Time Period	Median Available Flow (cfs)	10% Exceedance – Wet Year (cfs)	90% Exceedance – Dry Year (cfs)
October	18,598	31,998	11,143
November	0	41,254	0
December	13,375	49,401	0
January	35,169	78,113	0
February	17,154	87,791	0
March	44,010	89,180	0
April 1-15	10,899	45,265	0
April 16-30	0	42,223	0
May	13,018	83,221	0
June	14,986	142,807	0
July	0	86,307	0
August 1-15	0	1,671	0
August 16-31	0	0	0
September	15,720	26,380	9,450
Total (acre-feet)	**16,855,249**	**36,978,035**	**2,229,275**

Future Conditions

Columbia River water availability for future conditions was estimated using the flows from the BPA HydSim model for the Columbia River, and making adjustments based on estimated future conditions. Future conditions assumed for this evaluation included revised streamflow due to climate change and reduced streamflow due to additional demand and other projects that would divert water from the Columbia River upstream of the proposed Switzler Reservoir.

Future conditions used for this analysis incorporated streamflow changes caused by climate change, as projected by the Climate Impacts Group at the Priest Rapids, McNary, and Bonneville dam locations (Hamlet et al., 2010). The Climate Impacts Group developed average monthly streamflows for historical conditions from water years 1916 to 2006, and estimated streamflows for future conditions for those same water years using 19 climate change models and six future condition scenarios. The Climate Impact Group's 2040s B1 scenario was selected for this analysis to represent future changes in the Columbia River flows. The climate model results were downloaded from the Columbia Basin Climate Change Scenarios Project website at http://www.hydro.washington.edu/2860/. The Climate Impacts Group at the University of Washington produced these materials in collaboration with Ecology, BPA, Northwest Power and Conservation Council, Oregon Water Resources Department, and the British Columbia Ministry of the Environment.

Future demand for the Columbia River water supply was estimated using values in Ecology's *2011 Technical Report for the Columbia River Basin Long-Term Supply and Demand Forecast* (Ecology, 2011). This report forecasted 170,000 acre-feet of new irrigation demand in the Columbia River Basin by 2030, 117,500 acre-feet of new municipal and domestic demand by 2030, and 164,000 acre-feet of demand for the

Odessa Subarea. For this evaluation, it was assumed that these additional demands would reduce future availability of Columbia River flows as follows:

- New irrigation demand would reduce flows by 470 cfs from April to September;
- Municipal and domestic demand would reduce flows by 165 cfs year-round; and
- New demand for the Odessa Subarea would reduce flows by 2,700 cfs in October.

The evaluation of future conditions for this project did not take into account potential changes in the Columbia River Treaty, potential pumping from the Columbia River to supply the Yakima River basin or land in the State of Oregon, potential future changes to BiOp flow targets, or other future projects. These factors may change the amount of water available in the Columbia River. Table 3-2 summarizes the estimated Columbia River water availability for future conditions, applying the aforementioned assumptions.

Table 3-2. Estimated Columbia River Water Availability – Future Conditions

Time Period	50% Exceedance – Average Year (cfs)	10% Exceedance – Wet Year (cfs)	90% Exceedance – Dry Year (cfs)
October	15,512	28,872	8,079
November	12,341	58,711	4,444
December	47,375	102,206	23,717
January	82,896	141,933	33,708
February	73,110	171,412	35,119
March	87,219	147,274	26,225
April 1-15	36,133	78,816	0
April 16-30	2,389	86,699	0
May	29,310	108,634	0
June	0	102,033	0
July	0	32,480	0
August 1-15	0	0	0
August 16-31	0	0	0
September	16,570	27,453	10,169
Total (acre-feet)	**26,998,586**	**53,001,320**	**11,197,697**

3.1.2 Demands

The evaluation of Switzler Reservoir operations assumed that new water demands supplied by the proposed project would be distributed through the irrigation season according to the monthly demand distribution outlined in Section 4.1 of *the Horse Heaven Water Storage Pre-feasibility Report* (Aspect and Anchor QEA, 2010). Table 3-3 summarizes the monthly demand distribution, which was assumed to apply to both existing and future conditions.

Table 3-3. Assumed Monthly Irrigation Demand Distribution (Existing and Future)

Month	Demand
May	1%
June	14%
July	36%
August	32%
September	15%
October	2%

3.1.3 Reservoir Capacity

Maximum reservoir capacity was estimated to be 44,133 acre-feet, assuming the size and configuration of the dam described in Section 4.2. The dam crest would be at an elevation of 790 feet (NGVD 29) and the maximum operating water surface elevation would be at an elevation of 785 feet (NGVD 29).

3.1.4 Pumping and Inlet/Outlet Facilities Capacity

A range of maximum pumping and inlet/outlet facility capacities were evaluated in a preliminary effort to optimize the size and cost of the facilities relative to new demand that can be supplied by the project. Larger pumping and inlet/outlet facilities would enable the reservoir to fill more quickly when excess water is available in the Columbia River, which would increase the annual volume of water that could reliably be supplied by the project. The evaluation assumed that pumping and inlet/outlet facilities would be sized according to the following minimum acceptable reliability criteria:

- At least 75% of the targeted new annual demand would need to be supplied with 100% reliability; and
- The project would need to supply the full targeted new annual demand with 90% reliability.

In other words, the facilities would be designed so that water users relying on the new supply would only have to reduce their water use 1 out of every 10 years, on average, and water users would never have to reduce their water use more than 25%. The 1-in-10 years reduction in water supply represents a drought condition. The level of minimum acceptable reliability for the project would need to be confirmed as part of future analyses based on input from irrigators.

Inlet/outlet facility capacity will also need to accommodate peak release rates from the reservoir. The preliminary evaluation assumes that the maximum release rate would be equal to the rate required to meet demands during July, the month with the greatest demands.

3.2 Model Calculations

A spreadsheet model was developed to evaluate project operations and estimate the level of demand that could be supplied at various levels of reliability using the constraints and assumptions described in Section 3.1. The spreadsheet model was designed to calculate water availability, pumping and release rates, reservoir levels, and demand supplied on a monthly basis. The starting reservoir storage volume was assumed to be 44,133 acre-feet (full reservoir volume).

The following summarizes the spreadsheet model's logic and calculations:

- The model estimates flow availability for a given month in the Columbia River based on the BPA HydSIM model described previously and 2010 BiOp requirements.
- The model determines the level of demand to be supplied by the project for the month based on a total targeted annual demand volume input, distributed based on the monthly demand distribution outlined in Table 3-3.
- If there is water available in the Columbia River and the monthly demand is greater than zero, the demand is supplied directly from the Columbia River and the reservoir is not used.
- If there is water available in the Columbia River and the available volume of water exceeds the demand for the month, the model delivers water to the reservoir according to a maximum pumping rate, until the reservoir is full.
- If there is not enough water available in the Columbia River to supply the demand for the month, water is released from the reservoir up to a maximum release rate to satisfy the demand, unless the reservoir is empty.
- The reliability of the water supply is calculated on an annual basis by estimating the probability at which the targeted annual demand can be supplied in a year.

3.3 Model Results

The spreadsheet model described in Section 3.2 was used to estimate the level of new demand that could reliably be supplied by the project based on a variety of pumping rates, operational conditions, and existing Columbia River water availability. Initially, the model was used to estimate reliability for a variety of pumping rates based on a targeted annual new project demand of 44,000 acre-feet, which is roughly equal to the capacity of the reservoir. Figure 3-1 shows these results. The analysis assumed that the full reservoir capacity would be used, rather than reserving carry-over storage from year to year. The results illustrated on Figure 3-1 indicate the following for a targeted new annual demand of 44,000 acre-feet:

- With a 150-cfs pump station, the project would be able to supply about 57% of the targeted new demand with 100% reliability. The project would be able to supply about 95% of the targeted new demand with 90% reliability (9 out of 10 years).
- With a 200-cfs pump station, the project would be able to supply about 71% of the targeted new demand with 100% reliability. The project would be able to supply more than 99% of the targeted new demand with 90% reliability (9 out of 10 years).
- With a 300-cfs pump station, the project would be able to supply 44,000 acre-feet of demand with 100% reliability.

Based on these initial results, if the project was designed with a 150-cfs pump station, the project would not be able to supply a targeted demand equal to the reservoir capacity while meeting the minimum reliability criteria outlined in Section 3.1.4. If the pump station size was increased to 200 cfs, the project would nearly meet the minimum reliability criteria. Additional analyses were completed to evaluate the level of demand that could be supplied by the project with pump station capacities of 150 cfs and 200 cfs while meeting the minimum reliability criteria listed in Section 3.1.4. The following two scenarios were evaluated:

- Scenario 1 – Existing Columbia River availability conditions with a 150-cfs pump and use of the full reservoir capacity (no carry-over storage); and
- Scenario 2 – Existing Columbia River availability conditions with a 200-cfs pump and use of the full reservoir capacity (no carry-over storage).

Table 3-4 summarizes the results of the initial analysis and the two additional scenarios that were modeled.

Table 3-4. Operational Analysis Results for Existing Conditions

	Initial Analysis			Scenario 1	Scenario 2
Targeted New Annual Demand (Acre-feet)	44,000	44,000	44,000	35,480	41,080
Pumping and Transmission Capacity (cfs)	150	200	250	150	200
Reservoir Capacity (Acre-feet)	44,133	44,133	44,133	44,133	44,133
75% of Targeted New Annual Demand (Acre-feet)	33,000	33,000	33,000	26,600	30,800
Maximum Annual Reservoir Release (Acre-feet)	44,000	44,000	44,000	44,133	44,133
Reliability of Supply for Targeted New Annual Demand (%)	87.0%	89.9%	95.7%	97.2%	91.4%
Annual Demand that Can be Supplied with 90% Reliability (Acre-feet)	41,743	43,739	44,000	35,480	41,080
Results Shown in Figure	3-1	3-1	3-1	3-2	3-3

The results of the additional analysis of existing conditions are illustrated on Figures 3-2 and 3-3. The following summarizes the results based pump station sizing.

3.3.1 150-cfs Pumping Capacity

The results indicate the following for a pump station and transmission facilities designed to deliver a maximum flow of 150 cfs to the reservoir:

- The project would be able to supply a targeted maximum annual demand of 35,480 acre-feet, while meeting the minimum reliability criteria outlined in Section 3.1.4. The project would be able to supply that level of demand with a reliability of more than 97%.
- The project would be able to supply 26,600 acre-feet, or 75% of the maximum targeted annual demand, with 100% reliability.

The analysis assumed that the full reservoir capacity would be used to supply new demand. Analysis was also completed to determine any impact that would occur if only

80% of the reservoir capacity was used to meet annual demand and 20% was reserved for carry-over storage. The maximum demand that can be supplied by the project is primarily constrained by the criteria that requires that 75% of the maximum targeted annual demand to be supplied with 100% reliability. The results indicate that the minimum reliability criteria limit the level of demand that can be supplied to the amount shown regardless of carry-over storage.

3.3.2 200-cfs Pumping Capacity

The results indicate the following for a pump station and transmission facilities designed to deliver a maximum flow of 200 cfs to the reservoir:

- The project would be able to supply a targeted maximum annual demand of 41,080 acre-feet, while meeting the minimum reliability criteria outlined in Section 3.1.4. The project would be able to supply that level of demand with a reliability of more than 91%.
- The project would be able to supply 30,800 acre-feet, or 75% of the maximum targeted annual demand, with 100% reliability.

The analysis of carry-over storage was also completed for the 200-cfs pumping rate with similar results to the carry-over analysis for a 150-cfs pumping rate. The results indicate that the minimum reliability criteria limit the level of demand that can be supplied to the amount shown regardless of carry-over storage.

3.3.3 Future Conditions

The operational analysis was also used to evaluate the project under future Columbia River availability conditions. The same targeted project demands and pumping capacities that were evaluated for existing Columbia River conditions were also evaluated for future conditions as follows:

- Total new project demand of 35,480 acre-feet for a 150-cfs pump station; and
- Total new project demand of 41,080 acre-feet for a 200-cfs pump station.

The results of this analysis are presented on Figure 3-4 for the 150-cfs pump station and on Figure 3-5 for the 200-cfs pump station. For both scenarios, the results indicate that the project would be able to supply the targeted maximum annual project demand with a reliability exceeding 95%. The increased reliability under future conditions is due to a shift in water availability. Although increased demand throughout the Columbia Basin would reduce the overall availability of water, a shift in the hydrograph would increase availability in the late winter and early spring to allow for more pumping during that time, which would allow users to fill and use the capacity of the reservoir more consistently.

3.4 Summary of Operations and Additional Supply

It is recommended that a minimum pumping and transmission capacity of 200 cfs be considered for the proposed Switzler Reservoir project based on the results of this preliminary operational analysis. The analysis focused on identifying the level of new demand that could be supplied by the project based on supplying at least 75% of the annual demand with a reliability of 100% (drought year water supply) and supplying the total targeted annual demand with a reliability of at least 90% (9 out of 10 years).

Under existing Columbia River flow availability conditions, with a pumping and transmission capacity of 200 cfs and no carry-over storage, the project would be able to supply at least the following:

- A maximum annual demand of 41,080 acre-feet per year with 91% reliability
- 75% of the maximum annual demand, or 30,800 acre-feet per year, with 100% reliability

Including carry-over storage does not impact the level of demand that can be supplied by the project. The level of demand that can be supplied by the project is constrained by the requirement to supply 75% of the annual demand with 100% reliability.

Reservoir operations and supply will need to be flexible enough to accommodate changes in Columbia River water availability due to climate change and new demands added elsewhere in the basin. The analysis of future conditions indicates that these changes may increase the reliability of supply from the project. However, assumed future conditions and operational assumptions will need to be refined and evaluated in more detail during subsequent design phases, should the project proceed.

4 Refined Engineering Assumptions

Based on the Phase II refined engineering analysis, this section describes the current concepts for construction of the Switzler Reservoir project. A general description is provided first, followed by more detailed descriptions of the major project components.

4.1 General Description of Improvements

The proposed Switzler Reservoir involves the creation of new Columbia River off-channel storage within Switzler Canyon through construction of an embankment dam and appurtenances such as inlet/outlet works. The reservoir would be unlined and would be supplied with surface water from the Columbia River, which would be pumped from near the mouth of Switzler Canyon either through a combination of existing pump stations and/or a new pump station. Flows from upstream Switzler Canyon would provide a small additional source of inflow to the reservoir, considered negligible at this appraisal phase.

The improvements also include the construction of new pipeline from the reservoir to the Columbia River, which would serve as conveyance for both the supply (filling) and discharge (release). Other improvements include relocation of existing infrastructure such as farm-to-market roadways and existing irrigation laterals. Environmental improvements necessary to mitigate for loss of wetland and shrub-steppe habitat have also been evaluated. A summary of general project criteria is provided in Table 4-1. An overview of major project improvements is shown on Figure 4-1.

Table 4-1. General Design Information[2]

Normal McNary Dam Pool Water Surface Elevation (ft)	340
Maximum Reservoir Water Surface Elevation (ft)	785
Minimum Reservoir Water Surface Elevation (ft)	485
Maximum Reservoir Water Depth (ft)	300
Embankment Crest Elevation (ft)	790
Maximum Embankment Height (ft)	325
Maximum Pool Area (acre)	415

Note: ft = feet

4.2 Embankment Dam

4.2.1 Locally Available Earth Materials

The selection of the most economically feasible embankment dam section depends heavily upon the availability of competent building materials in close proximity of the site, to limit transport distance to the extent feasible. The embankment itself is estimated to require approximately 4 million cubic yards of material. Due to the magnitude of material volume necessary, locally available materials have been considered in developing the refined embankment engineering and cost estimate.

Two general geologic materials types are predominantly available in significant quantities within the immediate project vicinity. The first is Quaternary loess (wind-deposited silt and fine sand) which occurs at the surface in thicknesses ranging from several feet to possibly over 30 feet. The second material is the underlying basalt which generally occurs below the Quaternary soil units; it is locally exposed in scattered outcrops along the canyon walls. Basalt is also exposed in a small rock quarry on the west fork of Switzler Canyon.

The loess is composed of silt and fine sand that is generally non-cohesive. When unsaturated, it stands without support on slopes as steep as 36 degrees. It is moderately permeable to infiltration or groundwater flow. Due to loess' small particle sizes and lack of cohesion, it is highly susceptible to erosion from flowing water, and is moderately to highly susceptible to erosion from strong wind. Loess will be difficult to compact in its natural state and will be moderately moisture sensitive. When amended with cement or bentonite clay, it may make an ideal low-permeability dam core material. The Recent Alluvium present in the canyon bottom is generally composed of silt and fine sand, similar in gradation to the loess that mantles the upper slopes. Aside from its higher natural moisture content, the alluvium is expected to have geotechnical characteristics similar to the loess deposits when incorporated into an engineered fill.

Glacial outburst flood deposits (or colluvium derived from flood deposits) composed of clean sand and gravel were identified below the surficial loess deposits along the canyon walls in several gullies eroded through the loess. The material properties and quantities of the flood deposits, and potentially other soil materials present at the site, have not been determined through subsurface exploration, but may yield significant quantities of unconsolidated material ranging from silt to clean sand and gravel.

[2] Elevations relative to NGVD 29 (feet).

Basalt was observed in outcrops and within a quarry on the west fork of Switzler Canyon. Where exposed in outcrops, basalt forms steep to vertical cliffs that are subject to very slow raveling. Talus is present below several steep natural outcrops of basalt, and where sufficient quantities are present, it may be a minable rock fill resource.

Basalt observed in outcrop and in quarry sections in the site area was noted to be generally medium hard to hard, slightly weathered, and to generally have closely spaced fracture joints without significant mineral infilling in fractures. The nature of the hard rock with closely spaced internal fractures makes it an ideal material for producing rock fill. It is commonly quarried by blasting, with minimal crushing required to obtain fragments with variable sizes and a range of dimensions suitable for embankment fill and armor rock.

4.2.2 Embankment Dam Configuration

Embankment Location and General Configuration

The crest centerline of the proposed embankment would be situated approximately 1.1-miles upstream of the confluence of the Switzler drainage with the Columbia River (refer to Figure 2-1). At this location, the canyon narrows, which would allow for the minimum earthwork necessary to construct the embankment while providing for a useable storage volume of 44,000 acre-feet. Existing grade at the proposed embankment dam toe is approximately 465 feet, while the finished grade at the crest of the dam would be approximately 790 feet, which would create an embankment height of approximately 325 feet. Maximum water surface elevation would be 785 feet, which accounts for 5 feet of freeboard.

Crest length at this preferred location is approximately 2,000 linear feet. For the purpose of this project, a crest width of 25 feet was assumed. A conceptual plan and section of embankment dam is shown on Figure 4-2.

Other locations (both upstream and downstream) were considered for potential siting but were found to be unfavorable due to the excessive material volume required for construction, loss of potential mitigation habitat (if shifted downstream), and loss of potential storage volume (if shifted upstream).

Embankment Section

Several embankment dam sections were considered based upon available construction materials, including both rockfill and earthfill sections. A concrete arch section was excluded from consideration due to the excessive width of the canyon.

Due to the lack of sufficient quantities of suitable earthen material within relatively close proximity to the site, an earthen dam section as previously considered during the 2010 pre-feasibility assessment was considered infeasible and excluded from consideration. In order to construct an earthen section, the majority of required material would be imported from distant off-site sources, and a much larger (flatter side slopes) section would be required than for other sections such as those with rockfill composition.

For this appraisal assessment, two distinct rockfill dam sections were considered. The first section is a zoned rockfill dam with an impermeable central membrane core; the second is a decked rockfill dam with a concrete face membrane. For both sections, the anticipated upstream and downstream slopes are 1.8:1 and 1.5:1 (horizontal : vertical), respectively, based upon preliminary engineering. The design of the sections was confirmed to meet the Washington State Dam Safety Guidelines for both static and seismic conditions. Conceptual dam sections for both section alternatives are shown on Figure 4-3. The two alternatives are further described below.

1) Zoned Rockfill Alternative (Central Impermeable Core)

The zoned rockfill section alternative involves the construction of an embankment with three distinct zones. The first major zone is the rock shell material that comprises the outer regions of the embankment and is represented in the greatest overall quantities. The rock shell would be composed of large shot-rock / riprap type material that would be recruited from the canyon walls, likely through blasting. In general, the material for the rock shell would be well graded from 8-inches to 36-inches in diameter. Multiple sub-zones within the rock-shell zone would exist, with relatively larger well-graded materials on the exterior regions versus smaller well-graded materials towards the interior. The external surface of the rock shell would contain the largest rock, which would consist of interlocking riprap material.

The second zone would be the central impermeable core. This material would be placed along the longitudinal axis of the dam and would serve as the primary seepage barrier. Material required for the core would be of low-permeability inorganic clays or silts with a plasticity index greater than or equal to (≥) 10 to allow the core to deform without cracking. Local and regionally available material do not meet these criteria; therefore, both importing suitable clay material from off-site sources and amending on-site sources with cement/bentonite were explored in refining assumptions and developing cost estimates. Considerations related to the costs of both the clay and amended soil core are discussed in more detail in Section 5 of this report.

The final zone would be the filter and drain material placed between the rockfill zone and the central impermeable core. The purposes of the filter and drain material are to relieve uplift pressure from seepage, readily permit discharge of seepage from the foundation/abutments, and prevent piping (loss) of fine grain material from the core through the outer zones. Due to the high variation in gradation between the core and rockfill material, multiple filter zones that overlay one another may be required. While a suitable on-site source of naturally occurring filter material does not likely exist, there are several permitted gravel mines within close proximity (within 20 miles) of the site. Furthermore, the economics of the quarry rock production from within the canyon may lend itself to filter material production through on-site processing (crushing and screening). Table 4-2 presents estimated material volumes associated with the zoned rockfill alternative.

Table 4-2 Zoned Rockfill Alternative Material Volume Estimates

Item	Quantity
Core Material (CY)	1,000,000
Rockfill (CY)	2,890,000
Filter Zone (CY)	260,000
Total (CY)	4,150,000

Note: CY = cubic yards

2) Decked Rockfill Alternative (Upstream Concrete Face)

Similar to the zoned rockfill section, the decked rockfill section involves the construction of an embankment with several distinct zones. In this section, the vast majority of the embankment would be constructed of shot-rock recruited from the available basalt present in the canyon walls, likely through blasting. Like the central core section, rock material would be well graded, approximately from 8-inches to 36-inches in diameter, and would occupy several sub-zones, with the largest well-graded material being placed in the downstream and lower regions. Relatively smaller, well-graded rock would be placed progressively closer to the upstream face.

Second, a cushion zone consisting of well-graded rock (approximately 3-inch maximum size) approximately 15-feet thick would be placed between the rockfill and the upstream membrane. A base course layer consisting of finer, well-graded material would likely be placed below the membrane to facilitate installation of the membrane itself.

The upstream face membrane could be constructed of a variety of materials; however, the most commonly used, and that considered for this project, is reinforced concrete. The concrete membrane would be approximately 12-inches thick and would be reinforced with steel bars both horizontally and vertically. Concrete membranes on embankment dams are usually installed through the use of slip forms which climb the dam face facilitating a continuous pour of fixed width. Waterstops are generally placed between concrete pours to form watertight joints. Additionally, the concrete face is sealed along the foundation and abutments through construction of a cutoff trench (plinth) along the full perimeter of the membrane.

Table 4-3 presents the estimated material volumes associated with the decked rockfill alternative.

Table 4-3. Decked Rockfill Alternative Material Volume Estimates

Item	Quantity
Rockfill (CY)	3,955,000
Cushion Zone for Concrete Face (CY)	195,000
Total (CY)	4,150,000

Note: CY = cubic yards

4.2.3 Spillway

The proposed reservoir would require a spillway, designed according to the requirements of the Dam Safety Office (DSO) of Ecology. For water projects with dams and reservoirs designed to impound 10 acre-feet or more, the DSO requires that drawings, specifications, calculations, and other documentation be submitted for review prior to issuing a permit. Calculations for the following hydrologic characteristics of a proposed reservoir site are required by DSO:

- **Probable Maximum Precipitation (PMP) –** *Hydrometeorological (HMR) Report No. 57* (NOAA,1994) defines the PMP as “theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year.”
- **Probable Maximum Flood (PMF)** – The PMF is the largest flood to be expected assuming complete coincidence of all factors that would produce the heaviest

rainfall and maximum runoff. The PMF is estimated by routing the PMP through the watershed and reservoir using a hydrologic model.

- **100-Year Flood** – A flood with a 1% chance of occurring in a given year.

A detailed analysis of the PMP, PMF, and 100-year flood is beyond the scope of this study and would be completed as part the detailed design of the facility. However, preliminary estimates of the PMP, PMF, and the 100-year flood were calculated using readily available information for the sake of sizing and developing conceptual opinions of cost for spillway facilities.

PMP and PMF Estimate

PMP calculations are typically based on the methodology outlined in HMR No. 57 (NOAA, 1994). The PMF is then derived from the PMP estimate using the U.S. Army Corps of Engineers (USACE) HEC-HMS software or other computer model capable of simulating watershed response to precipitation events. That level of analysis is beyond the scope of this study, but would need to be completed during subsequent detailed design of the project. For the sake of providing preliminary sizing and costs for spillway facilities, rough estimates of the PMP and PMF were developed using unit flow rates from a preliminary spillway analysis that was recently completed for a reservoir project in the Yakima River basin with similar watershed characteristics.

The unpublished analysis was completed by Anchor QEA for a re-regulation reservoir planned for a tributary canyon on the north side of the Yakima Valley. The proposed re-regulation reservoir would be located at the mouth of a 14.5-square-mile drainage basin with temperature, precipitation, land cover, and geological characteristics similar to those in Switzler Canyon. The unit PMF from that analysis was used to roughly estimate the PMF for the 30-square-mile Switzler Reservoir drainage basin.

According to NOAA (1994), there are two types of extreme storm events that may occur at the proposed reservoir location, including the following:

- **General Storms** – General storms are significant events of intense precipitation lasting between 6 and 72 hours, and sometimes continuing for up to 96 hours. General storms typically cover areas between 500 and 10,000 square miles.
- **Local Storms** – A local storm is defined as an extreme rainfall event not associated with widespread heavy precipitation producing rain for 6 hours or less and concentrated over an area of 500 square miles or less. Local storms may occur by themselves or as part of larger storm systems, and they usually occur as thunderstorms.

The analysis of the re-regulation reservoir indicated that the PMP would be a local storm. The design PMF resulting from a local storm for the 14.5-square-mile re-regulation reservoir drainage basin was estimated to have a peak flow rate of 5,400 cfs. Based on the size of the drainage basin, the peak flow is equal to a unit flow rate of approximately 372 cfs per square mile. If that unit flow rate is multiplied by the drainage basin area upstream of the proposed dam in Switzler Canyon (30 square miles), the design PMF would have a peak flow of 11,160 cfs.

100-Year Design Flood Estimate

Design 100-year flows are typically developed in accordance with DSO's *Dam Safety Guidelines, Technical Note 3: Design Storm Construction* (Ecology, 2009). This level of analysis is also beyond the scope of this study but would need to be completed during the detailed design of the project. Estimates of the 100-year flood were calculated for this study using the USGS StreamStats tool (USGS, 2012). StreamStats estimates basin characteristics and flow statistics for ungaged watershed areas based on regression equations developed for different climatic regions in Washington State. The regression equations are based on data from gaged watersheds.

The StreamStats tool estimated that a 100-year peak flow from the 30-square-mile drainage basin upstream of the proposed dam in Switzler Canyon would result in a peak flow rate of 1,800 cfs. The StreamStats results are summarized in Table 4-4.

Table 4-4. Estimated Recurrence Interval Peak Flows – Switzler Canyon

Recurrence Interval	Flow (cfs)
2-year	176
10-year	625
25-year	1,000
50-year	1,360
100-year	1,800
500-year	3,170

Preliminary Spillway Sizing

A PMF of 11,160 cfs was used to develop a rough estimate of the size and cost of required spillway facilities for the proposed Switzler Reservoir. Additional analysis would be required during detailed design of the project to estimate the PMF based on guidelines from DSO and NOAA, as noted earlier in this section. Two potential configurations were identified for the spillway:

- A side-channel spillway along the east or west edge of the proposed reservoir with a chute near the edge of the dam to a stilling basin near the toe of the dam; or
- A drop-inlet, or morning glory, type of spillway with two drop inlets that would discharge through tunnels near the top of the dam to a chute that would convey water along the edge of the dam to a stilling basin near the toe of the dam.

The crest of the spillway was assumed to be at an elevation of 785 feet NGVD for both of these options. It was also assumed that the spillway would need to be sized to maintain at least 2 feet of freeboard in the reservoir below the dam-crest elevation (790 feet NGVD) while passing the PMF. That means the spillway would need to pass the PMF with no more than 3 feet of head over the side-channel weir.

Preliminary sizing of the side-channel type of spillway with a chute and stilling basin were completed based on design guidelines provided in the *Design of Small Dams* (U.S. Bureau of Reclamation, 1987). The side-channel configuration is shown on Figure 4-4.

Preliminary calculations indicate that the side-channel spillway system would need to include the following:

- A 650-foot-long, reinforced concrete side channel with a weir crest on the reservoir side of the channel at an elevation of 785 feet and a top elevation of 790 feet. The side channel would have a bottom slope of 2% and vary in depth below the crest from 12 feet to 25 feet. The width would vary from 24 feet at the upstream end to 50 feet at the downstream end.
- A 900-foot-long, reinforced concrete chute installed along the canyon wall near the side of the downstream face of the dam. The invert of the chute would have a bottom slope of approximately 32%. The chute would be approximately 50-feet wide with an average depth of 5 feet.
- A reinforced concrete baffled stilling basin. The stilling basin would be sized and designed to meet the requirements for the U.S. Bureau of Reclamation's Type II stilling basin design (refer to Figure 267, U.S. Bureau of Reclamation, 1987).

Preliminary sizing was also completed for a drop-inlet type of spillway according to guidelines provided by DSO. Preliminary calculations indicate that three 80-foot-diameter drop inlets would be required to pass the PMF with a maximum of 3 feet of head over the drop-inlet crest. Each drop inlet would discharge through a 12-foot-diameter tunnel near the crest of the dam. The size and requirements for the chute and spillway needed to convey water to the channel downstream of the dam would be similar to those outlined above for a side-channel type of spillway.

This preliminary spillway analysis does not indicate that there are any fatal flaws with the design and construction of a spillway to meet DSO requirements. However, a more detailed design analysis of the spillway will be required to meet DSO requirements, optimize the size of the spillway facilities, and refine the opinion of the probable construction costs.

4.2.4 Inlet and Outlet Works

An inlet/outlet pipeline would convey water supply from the pump station to the reservoir and water releases from the reservoir to the Columbia River, as described in Section 4.3.1. This section describes the conceptual inlet/outlet works at the reservoir that would be designed to control the flow of water to and from the reservoir. The inlet/outlet concept is illustrated on Figure 4-4.

The reservoir design would likely include a common inlet/outlet works. The inlet/outlet works would consist of a reinforced concrete structure located at the upstream toe of the dam. The structure would have an inclined upstream face open to the reservoir. The invert of the opening would be set above the bottom of the reservoir to allow for sediment deposition. The opening would extend vertically several feet. The opening would be covered by a debris rack consisting of steel bars spaced at 3 inches on center. For the purposes of redundancy, it is recommended that the open area and debris rack be sized approximately 80% larger than what is needed to carry the design discharge. For this analysis, the design discharge would be equal to the flow rate needed to meet the targeted new demand supplied by the reservoir during the month of July, which is the peak demand month. Assuming a 200-cfs pump station and full use of the reservoir capacity, as described in Section 3, the design release rate would be approximately 280 cfs. If the pump station is designed to deliver only 150 cfs, the design release rate would be approximately 260 cfs.

The inlet/outlet works structure would include two chambers. One chamber would serve as the typical intake for discharges from the reservoir, while the other chamber would serve as an emergency intake. The emergency intake would be used if the normal intake became plugged with debris during normal operations. Both chambers would be connected to the inlet/outlet conduit. The emergency intake would be isolated with a steel bulkhead gate, which attached to a stainless steel cable that would extend from the gate to the top of the dam. In the event that the primary intake gets clogged with debris, the cable would be used to open the gate of the pump intake structure, allowing water to discharge through the emergency intake chamber.

The inlet/outlet conduit would be the same size as the inlet/outlet pipeline between the pump station and the reservoir. The conduit would be buried under the dam along the bottom Switzler Canyon. The inlet/outlet conduit would likely be welded-steel pipe encased in concrete under the dam with concrete cutoff collars installed along the inlet/outlet conduit to prevent excess seepage. The need for cutoff collars around the conduit would be evaluated in more detail during detailed design of the dam.

A control valve or gate would be installed in a chamber of the inlet/outlet works, just downstream of the mouth the inlet/outlet pipeline. Because of the depth of water over the inlet/outlet, the valve or gate would need to be rated for high pressures (up to 300 feet or 130 pounds per square inch). The valve or gate operator would be motorized.

Near the downstream toe of the dam, the conduit would split into two branches. One branch would connect to the inlet/outlet pipeline and the other would provide for a low level discharge directly into the stream channel in lower Switzler Canyon. Control valves would be included on each branch to control flow into the inlet/outlet pipeline and the stream channel. A reinforced concrete structure would be installed at the end of the low-level outlet pipe where it discharges to the stream channel to dissipate energy. The energy dissipating structure would likely be a U.S. Bureau of Reclamation Type VI stilling basin.

4.2.5 Discharge Outfall to Columbia River

The inlet/outlet pipeline described below in Section 4.3.3 would be designed to convey water from Switzler Reservoir to the Columbia River. The pipeline would split into two branches near the pump station at the mouth of Switzler Canyon. One branch would be connected to the pump station discharge. The other branch would connect to an outfall designed to discharge reservoir water to the Columbia River.

The outfall pipeline would likely consist of buried steel pipe, with discharge fittings and a control valve. The pipe would be 72-inches or 84-inches in diameter, matching the diameter of the inlet/outlet pipeline described in Section 4.3.3. The control valve would be installed immediately downstream of the branch on the outfall pipeline. The outfall pipeline would extend beyond the small cove that supplies the existing pump station, along the stream channel through the railroad trestle opening to the Columbia River. It is anticipated that the outfall pipeline would be buried under the trestle on the west side of the trestle opening. The stream currently discharges through the trestle opening against the east abutment.

The outfall pipeline would extend into the river at a depth that will allow for constant submergence. A welded steel or flanged tee would be included at the end of the submerged outfall pipe to reduce discharge velocity and provide energy dissipation. It is not anticipated that the outfall would need to be screened for fish because the outfall would only operate to discharge water to the river.

4.3 Water Supply for Storage

The reservoir would be filled with surface water pumped from the Columbia River throughout the year when excess water is available in the river (Section 3.1.1 of this report). A majority of the water is available in the Columbia River during the winter months; therefore, hydraulic facilities must be thermally insulated from cold ambient temperatures in order to prevent freezing. Two methods for water supply pumping were originally considered as part of this study including construction of a new winterized pumping station and retrofiting (including winterization) existing pumping stations.

4.3.1 New Pump Station Infrastructure

A new Columbia River pump station capable of providing up to 200 cfs instantaneous flow at 475 feet total dynamic head (TDH) was evaluated as part of this study. This pump station would be situated in an existing lagoon at the base of Switzler Canyon, which is in hydraulic continuity with the Columbia River through a pair of 60-inch-diameter culverts submerged roughly 30 feet below the existing water surface. This station would be situated adjacent to the existing Irogrow pump station operated by Easterday Farms and would require reclamation of part of the existing lagoon, which was filled with sediment during a 2010 flooding event in the canyon.

The pump station would involve an array of eight 2,000-horsepower (hp) vertical turbine pumps which would be suspended from a pump deck into a wet well. In order to achieve the range of discharge pressure expected throughout the reservoir filling cycle, a combination of pumps in parallel operated off of variable-frequency drives would be preferred in order to optimize pumping efficiency and reduce power costs. During initial reservoir filling, only five of the eight pumps operating at full speed would be required due to the low head of the reservoir. As the reservoir fills, an increasing number of pumps operating at the most efficient speed would be required until the eight pumps operating at full speed are required.

Conveyance of surface water into the wet well would be through corrosion-resistant, vertical slotted fish screen panels submerged in the lagoon, which would have automated back-flushing or air-burst mechanisms to alleviate clogging. Fish screening would be designed to adhere to current requirements of the Washington Department of Fish and Wildlife (WDFW) and National Marine Fisheries Service (NMFS), which would include a maximum approach velocity of 0.33 feet per second (fps) measured 4 inches from the screen surface and a maximum slot width of 1.75 millimeters (0.069 inch).

In order to construct the wet well, dredging would be required to reclaim part of the existing lagoon, which was filled with sediment during a major runoff event in 2010.

The new pump station would include various mechanical and electrical components necessary to control and monitor flow, including check (backflow prevention) and isolation valves, flow metering, surge anticipator equipment, pressure sensors for emergency shutoff, motor control panels, and telemetry.

Due to the extensive horsepower and electrical requirements of the pump station, a dedicated power transformation substation may be required. An existing power substation adjacent to the existing Irogrow pump station may or may not have capacity and/or availability for use/expansion, but has not been evaluated specifically as part of this assessment. For the purpose of cost estimating of a new pump station, an entirely new power substation was assumed.

The mechanical and electrical components of the new pump station would be protected from the cold ambient air temperature by housing it within a new reinforced concrete-masonry unit (CMU) building equipped with heating and ventilation and cooling (HVAC).

Additional provisions for frost protection of surface water would also be required, including aeration of the lagoon to ensure that free-flowing surface water is available during the winter months.

A summary of data associated with a new pump station is shown in Table 4-5 and a conceptual plan for the surface water pumping station is shown on Figure 4-5.

Table 4-5 New Pump Station Data

Number of Pumps	8
Individual Pump Capacity (cfs)	25
Total Dynamic Head (ft)	475
Total Pump Horsepower	16,000
Pump Efficiency	85%
Motor Efficiency	80%
Pump Discharge Diameter (in)	20
Manifold Pipe Diameter (in)	60

Notes: cfs = cubic feet per second
ft = feet
in = inches

4.3.2 Existing Pumping and Conveyance Infrastructure

The 2010 pre-feasibility study identified the potential for using existing river pump stations which may have excess capacity. Under this concept, up to three existing pump stations within relatively close proximity of the dam site would be used in combination to fill the reservoir. While there may be some opportunity to capitalize on this existing infrastructure, it is likely that the three existing pump stations cannot provide sufficient capacity and reliability to provide for the duty conditions of the project. Furthermore, while it is believed that the controlling ownership interest of the project (Easterday Farms) is generally supportive of the project, use of these stations as required has not been negotiated. Potential season-of-use conflicts may also exist with local growers, which have not been explored in detail. Therefore, the use of existing pump stations was not progressed, and the cost estimates developed as part of this study and described in Section 5 of this report focus only on the new pump station scenario.

4.3.3 New Conveyance Pipeline

A proposed conveyance pipeline would connect the reservoir to the Columbia River and would double as the reservoir filling conveyance from the Columbia River pump station. Preliminary sizing calculations indicate that a minimum pipeline diameter of 84 inches would be required, which would equate to a maximum pipeline velocity of 5.2 fps at 200 cfs flow. Due to a combination of factors, including economics at the anticipated pipe diameter, and estimated water velocity and pressure, the pipeline would likely be constructed of cement-mortar-lined welded steel.

4.4 Environmental Mitigation

This section summarizes anticipated environmental mitigation provisions for the Switzler Reservoir project, which are characterized based upon field observations and findings from the following sources:

- Late September 2011 field reconnaissance, as summarized in the Phase 1 Appraisal Report (Aspect and Anchor QEA, 2012);
- Additional field observation that occured in early November 2012; and
- Research on wetland and shrub-steppe mitigation costs from Eastern Washington local and State government agencies.

These observations and research are summarized below in a description of general habitat conditions in Switzler Canyon. The summary includes information on topography and land use, hydrology and water quality, riparian and wetland vegetation, biota, and terrestrial habitat.

4.4.1 Topography and Land Use

As described in the Phase 1 assessment report (Aspect and Anchor QEA, 2012), Switzler Canyon is a steep canyon draining arid uplands. The channel width varies in the canyon, from approximately 10 to 50 feet, and is often confined by the steep hillslope topography. The flow in the stream channel in Switzler Canyon was historically much more intermittent. The channel sustains at least some flow throughout most of the year now, most likely as a result of irrigation return flow from agricultural activities upslope of Switzler Canyon. Approximately 2.2 river miles (RM) upstream from the Canyon’s outlet at the Columbia River, the channel splits into two forks: the west fork and the east fork. Where the two forks join to create the mainstem Switzler Canyon, the canyon bottom widens and the gradient drops, forming a large wetland complex. The stream channel meanders downstream from the confluence of these two forks, adjusting to the large sediment deposits from a large flood event in July 2011. The riparian zone extends across the entire low-gradient valley bottom.

Switzler Canyon as a whole has been heavily impacted by human activity. Impacts include conversion of the headwater drainage area to intensively irrigated agriculture and feedlots, grazing activities, road development, and stream and wetland modifications within the canyon itself. According to Easterday Farms staff (landowner of Switzler Canyon), many of the wetlands and associated pools within the canyon were developed in the 1990s to provide duck and other game bird habitat. Fish also were planted in the small pools (Ben Floyd personal communications with Dale Shelton on November 5, 2012).

The reach of the stream channel in Switzler Canyon approaching the Columbia River has been altered by the presence of the canyon road, an irrigation pump station, and a railroad crossing. Additionally, there have been wildfires and flood events. The major flood event of July 2011 deposited large amounts of sediment in the channel from the top of the west fork of Switzler Canyon downstream to the mouth. This sediment has since been moved into two berm areas to the east of the existing irrigation pump station. During a 2012 field visit, the channel appeared slightly more incised (narrower and a little deeper) in the sediment than was the case during the 2011 field visit.

At the mouth of Switzler Canyon at the Columbia River, the small stream channel outfall is perched approximately 3 to 5 feet above the water surface elevation of the Columbia River, as observed on November 5, 2012 (Anchor QEA field observation by Ben Floyd). The stream channel abuts the eastern side of the trestle, cutting through deposited sediment and existing vegetation (cattails [*Typhia* spp.]), and then discharging into the Columbia River by cascading down riprap at the shoreline.

4.4.2 Hydrology and Water Quality

In both the late September 2011 and early November 2012 field visits, streamflows were evident only where sustained by groundwater input. Flow came primarily from the west branch culvert outfall and was estimated at that time to be approximately 2 to 5 cfs. Water was present in the east fork of Switzler Canyon just upstream of the confluence of the two forks, but only to the point where the canyon road crosses the channel (RM 2.2). Some wetland vegetation existed north (upstream) of the road but no water was observed. Flows were also present in Switzler Canyon from the confluence of the two forks downstream to the Columbia River. Ponded water was visible in the wetland complex.

Water temperatures were measured at various points in the canyon in September 2011. The measured stream temperature just upstream of the confluence with the Columbia River at the canyon road crossing was 16 °C; at the Columbia River confluence, the measured stream temperature was 14 °C. Water temperatures in the west branch culvert outfall ranged from approximately 11 to 12 °C. Due to the irrigation groundwater seepage, there is high potential that the stream has elevated nitrogen and phosphorus levels, as well as other constituents associated with agricultural runoff.

4.4.3 Riparian and Wetland Vegetation

Throughout Switzler Canyon, dense mats of non-native species dominate the riparian corridor, limiting the establishment of typical native wetland-associated species. In the valley bottom, dense mats of thistle and common reed (*Phragmites australis*) are present, along with the occasional Russian olive tree (*Elaeagnus angustifolia*) and non-native Lombardy poplar (*Populus nigra*). Native species are present in limited areas: clumps of cattails on the valley floor, an aging grove of five cottonwoods (*Populus trichocarpa*) in the west fork, and a cottonwood grove of three trees near the mouth of the canyon at the Columbia River.

4.4.4 Biota

Fish passage from the Columbia River into the Switzler Canyon stream appears to be severely limited by the existing riprap and perched condition of the stream at the mouth of the canyon. Fish would only be expected in the channel in very low numbers, if at all. No fish species, aquatic insect larvae, amphibians, or crustaceans were observed within or adjacent to the stream channel in the 2011 and 2012 field visits. Fish were observed in the existing Easterday Farms irrigation intake pond just west of the stream and berms described above. Other documented wildlife included coyotes, deer, raccoon, hawks, pheasants (non-native game species), crows, flycatcher, and beaver.

4.4.5 Terrestrial Habitat

Shrub-steppe habitat is the dominant habitat type within the canyon and adjacent to the stream and wetlands. As previously stated, the uplands surrounding Switzler Canyon have been converted to agricultural and rangeland uses; therefore, existing shrub-steppe habitat in the canyon is mostly degraded and dominated by non-native plant species, especially where past ground disturbance has occurred. In a few instances, Lombardy poplars and cattails exist on otherwise dry hillslopes. These outcrops of riparian plants appeared to be supported by seepage of return flow from irrigation of upslope orchards to the east.

4.5 Potential Project Mitigation Elements

The construction and maintenance of a new pump station, conveyance pipeline, dam, and reservoir will have impacts to existing conditions within and adjacent to the project footprint. Federal, State, and local jurisdictions regulate critical areas such as wetlands and fish and wildlife habitat conservation areas, and also protect species that may be found within the project footprint. Likely mitigation elements for the regulated resources within the action area of the project are outlined below, including those for wetlands and associated buffers, aquatic habitat, and shrub steppe habitat. Resource areas, mitigation ratios, and associated costs were estimated based on rough calculations of impacted areas, professional judgment regarding the application of existing regulatory requirements, requirements from past and existing projects within the region, and guidance from local and state agencies. All assumptions should be refined through site specific analysis and detailed field investigations and discussions with regulatory agencies, during the upcoming detailed project feasibility analysis and design.

At this phase of project planning, these mitigation concepts can be considered potential options, the scale and details of which would be determined during specific negotiations with the permitting and resource agencies during the feasibility phase of the project.

4.5.1 Wetlands and Wetland Buffers

Approximately 10 acres of potentially jurisdictional wetlands and 20 acres of wetland buffer are located within the footprint of the proposed dam location and the associated reservoir. The wetlands are concentrated within the canyon valleys and are primarily emergent riparian and depressional wetlands which receive agricultural run-off during the growing season and into the early winter. The wetlands are largely dominated by non-native species such as thistle. The largest wetland area is just downstream of the confluence of the west and east branches (see Photo 5, Appendix C).

Mitigation for permanent impacts to jurisdictional wetlands is regulated by the US Army Corps of Engineers (USACE) and Washington State Department of Ecology (Ecology). Mitigation for impacts to wetland buffers is regulated by Ecology. Mitigation ratios for wetland creation, restoration, or preservation vary based on several factors, such as existing wetland functions, intensity of proposed land use, and type of impact(s). For purposes of estimating potential mitigation requirements, a conservative 2:1 replacement ratio has been assumed here. A lower replacement may be applicable based upon the quality of the wetlands constructed when compared to the limited functions of the existing wetlands. Mitigation ratios for wetland buffers also vary greatly based on the resources impacted. For this analysis these are assumed to be 1.5:1, which again is a conservative estimate. Using these ratios, wetland mitigation would be 20 acres of replacement wetland with 30 acres of replacement wetland buffer, for a total of 50 acres.

Wetlands and associated buffers could be located at the upper extents of the east and west branch areas of the reservoir, assuming an adequate water supply would be available in these areas from upland drainage and/or extension of the agricultural irrigation system to these areas. Additional wetlands could be established, or enhancement of existing wetlands could also occur, along the stream channel downstream of the dam and in the area next to the existing pump station.

4.5.2 Shrub Steppe Habitat

The reservoir footprint will inundate approximately 414 acres of existing habitat and resources. Of the 414 acres approximately 400 acres are considered Shrub Steppe habitat and this habitat is regulated by the WDFW. Based on past agreements and requirements the loss of shrub steppe habitat would likely require mitigation and or preservation at another location. In recent years, agreements have been developed among local agencies, Washington Department of Fish and Wildlife (WDFW), and Ecology, which have included an “In lieu Fee” to be paid to compensate for the shrub steppe habitat lost and the fee goes to purchase/preserve WDFW and Ecology preferred habitat in the local region.

4.5.3 Aquatic Habitat

Possible habitat mitigation has also been identified for the Switzler Canyon stream and Columbia River aquatic habitat. These areas will be affected by the large diameter inlet/outlet pipeline that will convey flow between the Columbia River and the reservoir. As described in Section 4.3, this pipeline will extend from the new pump station up to the reservoir and be located along the side of the canyon. The pipeline will release water back to the Columbia River through an outfall branching off the main pipeline. This 72 or 84-inch outfall pipe is expected to be routed underneath one side of the trestle bridge, and extend out into the river at a depth that will allow for constant submergence. A tee or other fitting will be provided at the end of the submerged outfall pipe, to reduce discharge velocity and dissipate energy. It is anticipated that the pipe will not require fish screening because water will only be discharged from the pipe and no intake will occur. Pictures 9 and 10 (Appendix C) depict typical conditions at the stream where it crosses under the existing railroad trestle and on the shoreline of the Columbia River.

The dam will also have a low-level outlet that will discharge directly to the Switzler Canyon stream channel. The stream channel in Switzler Canyon is not currently known to contain anadromous salmonids or other fish species, and because it is not a naturally occurring stream, it did not historically support a spawning or rearing population of salmonids. The closest spawning population of salmonids are summer steelhead located in the Walla Walla River, approximately 9.5 miles northeast of the project (WSCC 2001). Additionally, Rock Creek in the Umatilla basin supports steelhead and coho spawning (WPN 2009). Non-spawning steelhead and coho have observed using Rock and Wood

Gulch Creeks, and steelhead only have been observed in Pine Creek (WPN 2009). These subbasins are all approximately 30 to 60 miles downstream to the west of the project. Limiting factors for all of these salmon populations include quantity and quality of rearing habitat, namely adequate space, flow, temperatures, and instream and bank condition, and lack of spawning habitat (WPN 2009; WSCC 2001).

Construction impacts to aquatic habitats and species within the Switzler Canyon stream channel will be limited to riparian vegetation, substrate, and aquatic invertebrates, as there are no fish present in the channel. These impacts are expected to include potential increases in turbidity in the stream channel downstream of the soil-or sediment-disturbing work. There will also be a loss of stream habitat upstream of the dam. In addition, riparian vegetation will be removed or flooded to facilitate construction. Long-term changes from the project include alterations in flow patterns within Switzler Canyon. Invertebrates that may occur there will likely experience a change in flow periodicity and volume due to water control at the dam.

Construction impacts may also affect fish and aquatic species present near the stream's outlet at the Columbia River. These species may experience turbidity effects during or following upstream soil-or sediment-disturbing work. Similarly, existing sediment and naturally-occurring fines in the channel substrate as well as remaining deposited sediment from the 2011 flood event will be likely to enter the Columbia over a period of time following construction, due to increased flow releases from the dam outlet into the stream. Long-term changes will include the new stream outflow configuration at the mouth of the Canyon at the Columbia River, and changes to sediment dynamics in the Canyon. The new stream outflow configuration is expected to be a beneficial change, as fish and invertebrates will gain access to the stream channel and upstream habitat as a result of the project. Likewise, the dam will trap sediment upstream in the reservoir that would otherwise flow downstream. Significant sediment deposits have been observed in the stream channel below the dam.

This project presents several opportunities to improve the known limitations to aquatic habitat while providing mitigation for the project impacts. First, off-channel rearing and potential spawning habitat in the Switzler Canyon stream channel can be made available for Columbia River fish and aquatic species since the outflow can be made passable for fish and the stream channel can be enhanced for their use. For summer steelhead in particular, fish present in neighboring watersheds could potentially colonize or use the area for spawning, given appropriate flow and habitat conditions. This would be considered a likely outcome because the migratory behaviors and life history of steelhead lead to more straying from their home, or donor, population than some other Columbia River species (Keefer and Caudill 2012).

To facilitate this colonization in addition to the habitat enhancements to the stream, minimum flows would be provided year-round in the stream channel. A specific operating regime has yet to be developed but flows are preliminarily anticipated to range from 10 cubic feet per second (cfs) to 50 cfs. Flow releases to the stream channel should be evaluated to see how effectively these could mimic a natural hydrograph and the associated salmonid life stages that might exist in the stream channel if colonization occurs. Further evaluation at the design phase would be needed in order to determine the specific flow amounts by life stage that would be required to support this species, but generally flows would be expected to include larger spring flows to signal outmigration and adequate flows in other times of the year to support spawning and rearing. Upstream at the reservoir, the dam would be anticipated to trap naturally occurring sediment in stream water that would otherwise flow downstream. This effect would generally be considered a favorable outcome for salmon spawning habitat, as it would limit potential embeddedness limitations in spawning gravels. However, the dam would also trap terrestrial debris and detritus that support prey invertebrates, so downstream habitat will need to be high quality, with abundant riparian vegetation and diverse habitats with opportunities for instream input of this material

Opportunity exists for creation and enhancement of approximately one mile of stream aquatic habitat below the dam. This stream channel has the potential for providing suitable riparian and aquatic habitat to support salmonids, including creating meandering channels with woody debris and bank and instream habitat diversity. Diverse habitats create refuge areas for fish to find prey, rest during high flows, and hide to escape predation. Riparian vegetation throughout the existing streambank and wetland areas consist mostly of non-native vegetation that could be controlled and replanted with native plants and trees. Potential establishment of new riparian vegetation and wetland areas as well as enhancement of existing areas could provide needed temperature refuges for aquatic species as well as provide mitigation for the wetland acreage that will be removed upstream of the dam site.

4.6 Estimated Construction Timeframe

Overall, preliminary estimate of the construction timeline is anticipated to last approximately 5 years, which would require continuous construction for some elements. The initial phases of construction would involve mobilization, site preparation, foundation preparation, installation of an inlet/outlet tunnel, and diversion and care of water which may take a year or more to complete. It is anticipated that the construction of major embankment would occur over the following several years. Spillway, permanent site access, site security, and final surface restoration would complete the final phases.

Construction of the pumping station and conveyance pipeline would generally not be considered critical path items and could occur at any point within the project timeframe.

5 Refined Opinion of Probable Costs

An opinion of probable costs, including capital costs and ongoing O&M costs, was generated for the Switzler Reservoir during the pre-feasibility assessment (Aspect and Anchor QEA, 2010). These costs have been updated based upon refined engineering performed as part of this appraisal assessment.

This appraisal-level opinion of probable costs, while refined from the 2010 work, is still for planning purposes and should be considered order-of-magnitude. Costs were developed using a variety of methods and cost data sources, including RS Means/Costworks data, WSDOT Unit Bid Tabulations, and recent comparable projects. Also, during cost estimating exercises, a project estimator from a heavy civil earthwork construction firm was consulted to further refine estimated costs for major project components.

General assumptions used in developing the cost estimate included factors for mobilization/demobilization (10%); construction contingency (25%); Washington State sales tax (7.7%); indirect costs for survey, design, construction administration; and owner related overhead (15%).

Two alternative embankment dam sections were considered during cost estimating activities. Estimated construction costs for Alternative 1 (zoned rockfill) are approximately 10% higher than those for Alternative 2 (decked rockfill); therefore, the following discussion focuses primarily on the lower-cost decked rockfill alternative. Discussion regarding the variation in cost between the two embankment sections is provided in Section 5.1.4.

In total, the final opinion of probable project cost for capital improvements is approximately $281 million (2012 dollars), which includes contract costs for the construction of embankment and operational appurtenances, the Columbia River pump station, the conveyance pipeline, downstream channel improvements, and environmental mitigation improvements. The amortized annual capital cost based upon an interest rate of 4.0% with 50-year payback term is $13 million.

The capital cost ($281 million) also includes assumed non-contract costs for land acquisition and indirect costs such as feasibility studies, engineering (design and construction), permitting, and miscellaneous project administration.

Ongoing annual O&M costs are estimated at approximately $4.5 million. Based upon a 91% reliable supply of 41,080 acre-feet, the unit cost for water supply developed through storage (both capital and O&M) is estimated at $427 per acre-foot.

5.1 Capital Cost

5.1.1 General Description of Capital Costs

Capital costs encompass the construction of major infrastructure including project design, permitting, and land acquisition, but do not include O&M costs. The opinion of probable capital cost is summarized in Table 5-1, and additional detail regarding the estimated capital cost is provided in Appendix B.

The primary driving cost factors associated with the project capital costs are related to the construction (contract) phase. For the purpose of this appraisal assessment, construction costs have been organized into the following categories:

- General
- Site work
- Embankment Dam
- Operational Appurtenance
- Surface Water Pump Station
- Environmental Mitigation

Table 5-1 Opinion of Probable Capital Costs

Item	Cost
General	$18,590,000
Site Work	$20,519,000
Embankment Dam	$113,473,000
Operational Appurtenances	$11,552,000
Surface Water Pump Station	$14,297,000
Environmental Mitigation	$2,470,000
Construction (Contract) Cost Subtotal	**$180,901,000**
Construction Contingency (25%)	$45,225,000
Construction (Contract) Cost Subtotal, Incl. Contingency	**$226,126,000**
Washington State Sales Tax (7.7%)	$17,412,000
Contract Cost Total	**$243,538,000**
Land Acquisition	$450,000
Studies, Engineering, Permitting, and Project Administration	$36,531,000
Non-Contract Total	**$36,981,000**
Project Cost Total	**$280,519,000**

The assumptions related to each construction cost category (and major sub-categories) are described below.

5.1.2 General

For the purpose of this study, general work for the project includes mobilization and construction staging.

Mobilization

Mobilization involves costs associated with preconstruction expenses and preparatory operations performed by the contractor. These costs are generally associated with procurement of performance bonds (5% of the contract), and mobilization of equipment and other contractor-related operational expenses that are not associated with other contract items. The lump-sum estimate for mobilization on this project is approximately $18 million.

Construction Staging

The project will require well-developed staging to facilitate services for up to 100 personnel and up to 40 pieces of heavy machinery. It is anticipated that up to 15 office job trailers for professional services, changing, and feeding facilities would be required for the complete duration of the project. A maintenance yard with dedicated staff would also be necessary. For cost-estimating purposes, a staging site was assumed to be located at the southwestern rim of the canyon in an area that is presently undeveloped. The yard was assumed to be 5 acres in size, gravel surfaced, and fenced. An independent potable water system consisting of a new well, storage tank, and distribution piping would be constructed. Wastewater would be provided using portable toilets. It was assumed that power would be run from the nearby substation. The cost estimate for the construction staging area is approximately $560,000.

5.1.3 Site Work

Site work involves both site improvements during construction and final site improvements. Construction site activities would include construction of temporary access roadways, clearing and grubbing, stripping of topsoil, diversion and care of water, temporary erosion and sedimentation control (TESC), relocation of existing utilities, relocation of farm-to-market roadways, revegetation/property restoration, permanent access, and site fencing and security. A description of assumptions associated with the major site work elements follows.

Construction Access

Logistically, the project will be relatively complex, requiring transportation of materials, manpower, and equipment into and out of the canyon. The project will also require significant earthwork operations within the canyon itself, which will involve the transport of millions of cubic yards of material from quarry/source locations to various places of use, often requiring intermediate processing steps. It is anticipated for estimating purposes that the project will require approximately 4 miles of 30-foot-wide, temporary access roadway. This temporary access roadway will require an average approximately 10 cubic yards of grading (per foot), and 1 cubic yard of aggregate material per foot to construct at an average unit cost of $275 per foot for a total lump-sum cost of approximately $6 million.

Clearing and Grubbing and Stripping of Topsoil

Clearing and grubbing will be necessary to prevent organic, deleterious materials from mixing with competent stockpile sources. For purposes of the estimate, it was assumed that the top 6 to 12 inches of topsoil material contains high-organic content which has limited use on the project, with the possible exception of vegetative surface restoration. Approximately 230 acres of the site were estimated to require clearing and grubbing, which accounts for the complete footprint of the embankment and areas within the canyon identified for potential embankment source material. A unit price of $4,000 per acre was estimated for clearing and grubbing, which is typical of high-volume projects recently built in Washington State. The estimated cost for clearing and grubbing and stripping of topsoil is approximately $2.8 million.

Diversion and Care of Water

Switzler Canyon conveys water on a perennial basis through the canyon reaches. Natural base flows are assumed to consist primarily of irrigation return flows. Like many eastern Washington drainages, Switzler Canyon is susceptible to sudden flash flooding events (refer to Table 4-4). The continuous base flow, seasonal high flow, and potential flooding events must be managed and safely bypassed through the work zone throughout construction to protect human life and property and to preserve water quality.

For the purposes of this project, it is assumed that the sequencing of construction would allow for the construction of the permanent inlet/outlet conveyance (below the base of the dam) first. This would allow for diversion of water through piped conveyance as the major embankment is built. In order to allow for further flexibility of the workforce, and limit the amount of natural stream system that would need to be protected, it is assumed that the natural channel upstream of the inlet/outlet conveyance within the work zone would also be tight-lined (piped) through the duration of the project. It is assumed that a temporary drainage pipe of 96-inch diameter would be installed, consisting of either dual-wall HDPE, steel-spiral-bound HDPE, or corrugated; this steel pipe would be used for this purpose at an estimated cost of $500 per linear foot. Because the conveyance capacity at that pipe diameter may be limited to approximately 1,300 cfs (50-year event), temporary storage dikes may be required upstream of the work zone to provide peaking flow attenuation (storage) related to flash-flooding events. The estimated cost for diversion and care of water is approximately $2 million.

Temporary Erosion and Sedimentation Control

Temporary erosion and sedimentation (TESC) control includes on-site provisions necessary to prevent transfer of potentially pollutant-laden runoff (including sediment) from leaving the site in order to meet Federal National Pollutant Discharge Elimination System (NPDES) standards, which are administered by Ecology. TESC measures are also designed to limit accelerated unnatural erosion of existing features that could be impacted as a result of construction activities. TESC measures consist of stormwater and wind erosion best management practices (BMP), which commonly include silt fence, straw wattles, pipe-slope drains, temporary ditch conveyance, temporary slope protection, dust control watering, sedimentation basins, etc.

It is likely that a dedicated crew of manpower, including certified erosion control leads, and equipment will be necessary to constantly maintain, reconfigure, rebuild and supervise erosions control activities.

For cost estimating purposes, an aggregate average unit cost per acre of $5,000 was assumed, which reflects the relatively sensitive nature of nearby aquatic resources, challenging site conditions (steep slope and highly erodible materials), and the extended duration of the project. The estimated cost for TESC is approximately $2.5 million.

Relocation of Existing Utilities

Per conversation with the Easterday Farms farm manager, an existing 24-inch irrigation lateral crosses the west fork of Switzler Canyon at approximately RM 2.3. It is assumed that this lateral would be relocated to avoid conflict with the proposed area of inundation created by the reservoir. In order to relocate this lateral, an estimated 8,000 linear feet of new 24-inch-diameter pipeline is required at an average cost of $250 per foot for a total estimated cost of $2 million.

Relocation of Existing Farm-to-Market Roadway

An existing gravel roadway enters Switzler Canyon from the northwest which traverses the canyon to service agricultural lands situated to the east of the Canyon. This gravel roadway would be in conflict with the proposed area of inundation of the reservoir. It is uncertain whether this roadway could be relocated across the crest of the embankment due to security concerns. Therefore, an alternate alignment, which relocates this roadway around the perimeter of the reservoir, was assumed in the cost estimate. To perform this relocation, approximately 7 miles of gravel roadway would be required at an estimated cost of $0.5 million per mile. It is assumed that much of this roadway could occupy existing corridors and that improvements would be minimal, consisting of widening and resurfacing only.

5.1.4 Embankment Dam

The embankment dam construction will involve several phases from stripping and stockpiling of native material (for foundation preparation), foundation preparation and grouting, material recruitment, and processing, followed by embankment construction.

Stripping and Stockpiling of Material

Striping and stockpiling would include removal of overburden and unstable rock material from the dam footprint in order to prepare the foundation on sound bedrock. It is anticipated that 530,000 cubic yards of material would be removed for foundation preparation alone, 203,000 cubic yards of which would be loose silt and fine sand, and 327,000 cubic yards of which would be rock material that is either unstable or is in conflict with the footprint of the dam. For the central impermeable core alternative, the earthen material would be processed and amended with cement/bentonite or use as core material. In contrast, this material would be exported off site for the concrete-face alternative. The cost estimate was developed with unit prices of $4, $10, and $22 per cubic yard for soil excavation (to stockpile), soil excavation (export off site), and rock excavation, respectively.

Foundation Preparation

Foundation preparation would include treatment of the native rock substrate below the embankment to limit seepage and improve stability. This would involve both the construction of a cutoff trench (central core alternative) or plinth (upstream concrete-face alternative), as well as foundation grouting.

For the purpose of the cost estimate, it was assumed that a cutoff trench would involve excavation of rock (15-foot width and 15-foot depth) below the impermeable core. Similarly, dimensions for the plinth would be a 5-foot width by 10-foot depth along the complete length of the foundation and abutment walls.

The foundation and abutments would then be grouted through a series of drilled holes which would be injected with cement under pressure. This process would tighten, seal or otherwise fill joints, fractures, and various openings which could contribute to seepage below and around the embankment. The estimate includes an allowance for grouting that would accommodate a grid spacing of drilled holes at approximately 10-foot on center at $1,000 per hole.

Embankment Construction

The construction of the embankment would involve two major heavy civil operations. The first would involve the recruitment and processing of competent building materials from the various on-site sources, and the second would involve the construction of the embankment itself.

The primary building component for each of the alternatives considered is rockfill that would be extracted from the canyon walls through blasting once the overburden material has been stripped and stockpiled separately. Quantities of rockfill for the two alternatives are shown in Tables 4-2 and 4-3. Blasting methods vary but the most common and likely used on this project would be bench blasting. This would involve rock removal on a series of horizontal benches in which vertical holes and charges are placed and subsequently blasted towards a free surface. The end result of rock blasting material would be crushed rock of various gradations which could be mixed to meet the size and specification for rockfill. Further crushing and refinement of blasted rock could be performed to accommodate other uses on the project.

The unit cost for rock material was determined using RS Means/Costworks by combining rock blasting for large quarry operations with loading, haul, placement, and compaction. For the purpose of this estimate, it was assumed that blasted rock material would be placed in 50-ton, off-highway trucks with 7-yard power shovels. The haul route would vary and has been estimated at 2 miles per round trip in order to calculate an average unit cost; the average unit cost for rockfill was estimated at $23 per cubic yard.

Approximately 1,000,000 cubic yards of core material would be required for the zoned rockfill alternative. Natural competent material meeting the engineering properties required for impermeable core do not exist on site; however, use of existing materials once amended with cement/bentonite additive could be feasible. The estimated unit cost (per cubic yard) for amended on-site soils, haul, placement, and compaction is $45.

Import of clay material from off-site sources was also explored in the cost estimating process. The nearest currently operating off-site source for clay that was identified with sufficient quantities is located in Spokane, Washington, approximately 175 miles from the site. While materials from this location exist in sufficient quantities to support the project, it is uncertain whether the owner of the clay borrows would be willing to provide the required quantity of material. Transport of the material could occur by either truck or rail at an estimated cost of $40 per cubic yard (excluding material cost, placement, or compaction). It is estimated that the overall unit cost of the clay core would approach approximately $80 per cubic yard, which would represent a $35 per cubic yard premium over the amended soil core alternative. Other closer sources of clay may exist but overall costs to import are anticipated to be significant; therefore, the option of importing clay for the core was excluded from further consideration at this stage of the planning process.

Additional aggregate for filter zones (zoned alternative) and cushion (decked alternative) would also be required at 260,000 cubic yards and 195,000 cubic yards, respectively. The source of this material would ultimately be determined by construction economics at the time of bidding, but would either be purchased from nearby aggregate quarries or produced from on-site crushing/screening of blasted on-site rock. The estimated cost for import of filter material from off-site sources and the estimated cost for production from on-site materials are comparable, at an estimated unit cost of $26 per cubic yard.

The upstream concrete-face membrane alternative would require the placement of cast-in-place reinforced concrete over a cushion layer spanning the complete upstream surface area of the embankment. This membrane would be placed in vertical strips through the use of slip forms that would be raised from the base of the dam to the crest in continuous pours. For the purpose of this estimate, it was assumed that the concrete membrane would be approximately 12-inches thick, and poured in 24-foot-wide strips at a unit cost of $110 per square yard.

5.1.5 Operational Appurtenances

Operational appurtenances consist of water conveyance infrastructure necessary for movement of water into and out of the reservoir and protection from flooding events. For this project, operation appurtenances include inlet/outlet works, spillway/stilling, conveyance pipeline, and outfall.

Inlet/outlet Works

As noted in Section 4.2.4, the inlet/outlet works would consist of a reinforced concrete inlet/outlet structure near the upstream toe of the dam with a debris rack and other appurtenances, and a concrete-encased steel conduit buried below the dam with cutoff collars and appurtenances. Construction of the inlet/outlet works at the dam will involve excavation and soil preparation, placement of foundation material, forming and placement of reinforced concrete, trenching and backfill for the pipeline, and installation of welded steel pipe and appurtenances.

The preliminary opinion of cost developed for this study estimated that the following would be required:

- Approximately 1,700 cubic yards of reinforced concrete, including concrete encasement and cutoff collars for the inlet/outlet conduit;
- Approximately 1,120 feet of welded-steel pipeline;
- An 84-inch-diameter control gate or valve with motorized controls near the inlet/outlet structure;
- Two 84-inch-diameter control valves near the downstream toe of the dam to control flow to the creek and inlet/outlet pipeline;
- A reinforced concrete baffled outlet structure at the discharge from the low-level outlet to the stream channel in Switzler Canyon to dissipate energy; and
- Trenching, structural excavation, soil preparation, and backfill.

A unit cost of $600 per cubic yard was used for reinforced concrete. The steel pipeline was assumed to be 84-inches in diameter, which would correspond to a pump station designed with a 200-cfs capacity. A unit cost of $750 per foot was used for 84-inch-diameter steel pipe. The overall preliminary opinion of the probable costs associated with installation of the inlet/outlet works is $2.2 million.

Spillway/Stilling

Construction of the spillway would involve excavation and soil preparation, placement of foundation material, and forming and placement of reinforced concrete. The proposed spillway would consist of a reinforced concrete side channel along the east edge of the proposed reservoir upstream of the dam, a reinforced concrete chute descending down the east side of the canyon beyond the toe of the dam, and a reinforced concrete stilling basin at the downstream end of the side channel.

The sizing of the side channel, chute, and stilling basin were summarized in Section 4.2.3. The preliminary opinion of cost developed for this study estimated that more than

6,000 cubic yards of concrete would be required to construct the spillway facilities. A unit cost of $600 per cubic yard was used for reinforced concrete. Construction of the side channel would also require extensive excavation and soil preparation work and placement and compaction of on-site material to support these structures. The total preliminary opinion of the probable cost of spillway facilities is estimated at $4.3 million.

A sensitivity analysis was performed to determine the likely savings that would occur if the dam was raised so that additional hydraulic head would be available, which would reduce the length of the spillway. If the dam was 5 feet taller and the total head over the spillway crest was 10 feet instead of 5 feet, 8 feet of head would be allowed over the spillway crest. With the additional head available, the size of the side channel would be significantly reduced. The additional storage volume would also be available for attenuating the PMF flows, which could potentially reduce the size of the spillway facilities required even more. The analysis indicates that adding 5 feet of height to the dam could reduce the cost of spillway facilities by more than $2.3 million; however, the cost of the additional height to the dam costs is likely to be closer to $4 million. Overall, adding height to the dam would not likely result in project cost savings.

As was noted in Section 4.2.3, a full analysis of the PMF and other factors impacting the design of the spillway has not been completed. Additional analysis would be needed during subsequent design efforts to refine the sizing and opinion of cost for spillway facilities.

Conveyance Pipeline

The major conveyance pipeline between the proposed reservoir and the pump station would consist of an 84-inch-diameter, cement-mortar-lined welded steel pipeline. Approximately 5,800 linear feet of pipe would be required for this conveyance. Additional conveyance would be required for the proposed outfall and has been accounted for separately (see below). The estimated unit cost for the conveyance pipeline is approximately $660 per linear foot.

Outfall

As noted in Section 4.2.5, the outfall pipeline would consist of a steel pipe branching from the main inlet/outlet pipeline near the pump station to a discharge location in the Columbia River. This preliminary opinion of costs assumes that the outfall would include approximately 1,500 linear feet of steel or fused HDPE pipe, with a control valve at the upstream end and fittings at the discharge. Construction of the outfall would involve trenching and backfill for the pipeline, installation of welded steel pipe, and installation of valves, fittings, and other appurtenances.

The pipeline was assumed to be 84-inches in diameter, which would correspond to a pump station designed with a 200 cfs capacity. A unit cost of $750 per linear foot was used for 84-inch-diameter pipe. The overall preliminary opinion of the probable costs associated with installation of the inlet/outlet works is $1.3 million.

5.1.6 Surface Water Pump station

New Pump Station

As noted in Section 4.3.1, the construction of a new pumping station would involve site preparation, excavation/dredging, concrete structural work, fish screening, pumps and motors, valves, facility piping, motor controls building improvements, surface restoration and power supply. The pump station would be situated in the existing lagoon at the base of Switzler Canyon, adjacent to the existing Irogrow pump station owned and operated by Easterday Farms, and would pump water into the inlet/outlet conveyance pipeline dedicated to the reservoir.

Site Preparation and Excavation / Dredging

Site preparation for the pump station would involve clearing and grubbing, site grading for equipment, and material staging. It is assumed that the wet well would extend to a depth of 25 feet below normal pool elevation, which would require removal of approximately 2,000 cubic yards of material from in and around the wet well footprint. In order to perform the required excavation and subsequent installation of the wet well, it is assumed that a sheet piling both for cofferdam and for shoring would be required, as well as an extensive dewatering system, including dewatering wells and pumps. Furthermore, approximately 7,000 cubic yards of dredging would be required adjacent to the existing lagoon in order to provide adequate surface water supply to the new pump station. The estimated construction costs for site preparation and excavation/dredging is approximately $1.6 million.

Wet Well / Platform and Screened Intake

It is assumed that the pump station would include vertical turbine-style pumps suspended from a platform into a three-sided concrete wet well with a vertical screened intake on the fourth (river) side. For purposes of this estimate, the inside dimensions of the concrete wet well would be 80-feet long by 10-feet wide by 30-feet high with a reinforced concrete-wall thickness of 12 inches and a top-slab thickness of 18 inches (with 24-inch thickened beams underlying the pumps).

The screened intake was assumed to consist of a series of vertical slotted-panel screens sized for 200 cfs, 0.33 fps approach velocity (4 inches from screen surface), 10% misdistribution of flow, and additional area to account for clogging. The preliminary screen sizing is estimated at 1,110 square feet and would be divided evenly among the eight pumps at an estimated construction cost of $2 million.

Superstructure, Building Electrical, HVAC

The pump station would require winter-weather operation that will necessitate the construction of an insulated enclosed structure with heating, ventilation, and cooling. For the purposes of this estimate, a reinforced CMU building with metal roof was considered at a cost per square foot of $200. Minor appurtenances included in the building would include double doors for personnel and equipment access, skylight hatches for pump removal, building security system, and interior/exterior lighting. The estimated construction cost for the superstructure and building electrical and HVAC improvements is approximately $480,000.

Pumps, Mechanical, Valves, and Piping

In order to achieve a pumping rate of 200 cfs, eight 2,000-hp vertical turbine pumps in parallel were considered with a TDH of 475 feet. Pumps would be equipped with variable- frequency drives to meet seasonally increasing discharge pressure requirements. Each pump would be configured with an isolation valve and check valve immediately downstream of the pump discharge, and would also be equipped with a pressure switch for pump protection. The pumps would feed into a common manifold header pipe which has been preliminarily sized at 60-inches in diameter. The common header would exit the station and pass through a flow meter with instantaneous and totalizing functionality.

Due to the high-head duty condition, the station would be equipped with a surge anticipation station which would include surge relieve and anticipator equipment in case of power failure or otherwise sudden pump shutoff.

The total estimated construction cost for the pumps, mechanical, valves, and piping is approximately $5.8 million.

Motor Controls and Electrical Power Supply

The pump station would be equipped with MCCs that would control individual pump operation with programmable logic capability. Power supply to the station would involve a new power substation that could be sited nearby or possibly be integrated into an expansion of the nearby pump station for Irogrow. The estimated cost for pump controls and electrical power supply is approximately $3.8 million.

5.1.7 Environmental Mitigation

Wetland Mitigation

Planning-level costs were estimated for wetland and wetland-buffer mitigation. Estimated costs include land acquisition, pre- and post-monitoring, construction, and planting. The estimated costs are provided below:

- Land costs would include acquiring up to 50 acres at $4,000 per acre: cost up to $200,000;
- Pre/post monitoring costs: $100,000;
- Earthwork and flow conveyance/control: $200,000 ($10,000 per acre assumed unit cost for 20 acres);
- Soil amendment to help retain water in wetlands: $400,000 ($20,000 per acre assumed unit cost for 20 acres); and
- Planting costs: $250,000 ($5,000 per acre assumed unit cost for 50 acres).

Total estimated wetland mitigation cost: up to $1.15 million.

Refinement of this wetlands-mitigation cost estimate would involve more detailed site investigation and project design, and communications with regulatory agencies on specific compliance provisions to be addressed.

Shrub-Steppe Habitat Mitigation

As noted in Section 4.4.5, potential mitigation for loss of shrub-steppe habitat could include an “in lieu fee” to compensate for the shrub-steppe habitat lost. The fee would be used to purchase and preserve WDFW- and Ecology-preferred habitat in the local region. In a recent agreement among the Kennewick Irrigation District, WDFW, and Ecology, approximately $1,000,000 was paid to compensate for planned shrub-steppe habitat loss associated with the Red Mountain irrigation system development. The cost per acre was approximately $800. Applying these costs to the loss of approximately 400 acres of shrub-steppe, if Switzler Reservoir was developed, the estimated cost would be approximately $320,000; that cost would not include administration or contingency.

Downstream Channel Improvements

Downstream channel improvements will likely be needed to reinforce the channel against erosion and provide enhancements to mitigate aquatic habitat impacts. Additional study of the aquatic biology and stream channel geomorphology will be required to identify specific in-channel improvements. However, likely in-channel improvements will include:

- Placement of stream-channel rocks and boulders downstream of the low-level outlet to the stream and the spillway outlet to the stream to provide protection against erosion;
- Placement of wood and rock at selected locations in the stream channel to control the stream-channel grade and provide protection against erosion;
- Placement of wood and rock at selected locations to improve in-channel habitat; and
- Removal of riprap, grading, and placement of new rock and wood at the mouth of the stream channel to improve access for fish from the Columbia River for off-channel use in an effort to mitigate impacts to aquatic habitat.

Depending upon the level of stream-channel enhancements and desired timeframe for achieving these conditions, costs for channel improvements designed to improve aquatic habitat and connection to existing or proposed enhanced wetlands could range from $500,000 to $1 million for construction and post-construction monitoring.

5.2 Operations and Maintenance Cost

O&M costs consist of annual costs necessary for operating equipment, monitoring, and periodic maintenance and replacement of deteriorating components throughout the life cycle of the project. O&M costs vary by component and have been calculated by assigning factors based upon anticipated design life of various components. For the purposes of this estimate, O&M cost factors of 1%, 2% and 5% have been applied to the capital costs of the embankment dam, operational appurtenances, and pump station facility, respectively.

A major component of O&M costs are power costs associated with water pumping necessary to fill the reservoir, which were calculated based upon the Benton County Public Utility District’s (PUD) Rate Schedule for Large Agricultural Irrigation Without Annual Facilities Charges. Per that Rate Schedule, power costs (September 1 through March 31) are $0.0517/kwh (on peak) / $0.0439 (off peak) with a monthly demand charge of $2.87 per kw.

Table 5-2 summarizes estimated annual O&M costs.

Table 5-2 Estimated Annual Operations and Maintenance Cost

Item	Capital Cost	Annual O&M Cost	Annual Power Cost
Embankment Dam	$168,040,000	$1,680,000	N/A
Operational Appurtenances	$17,110,000	$342,000	N/A
Pump Station	$21,170,000	$1,059,000	$1,400,000
Total		**$3,081,000**	**$1,400,000**

5.3 Unit Water Cost

The estimated cost per acre-foot of water is $427 based upon the amortized annual capital cost and annual O & M cost distributed over 41,080 acre-feet. The amortized annual capital cost was calculated using the following assumptions:

- 4.0% interest rate
- 50-year loan repayment term

Table 5-3 below presents the estimated unit cost of water supply.

Table 5-3 Estimated Unit Water Cost

	Annual Cost	Annual Cost / Acre-Foot
Capital Cost	$13,058,216	$318
O&M Cost	$4,481,000	$109
Total	**$17, 539, 216**	**$427**

6 Permitting Process and Strategy

6.1 Applicable Permits

Described in this section are the applicable permitting requirements and likely timeframe for permitting reviews, and the suggested permitting strategy. Project development includes applying for and obtaining all relevant applicable Federal, State, and local permits. Table 6-1 lists standard permits and environmental reviews that would likely need to be obtained for the project, followed by narrative descriptions.

Table 6-1. Likely Federal, State, and Local Permits and Regulatory Approvals

Permit	Regulatory Agency	Apply with the JARPA (Y/N)	Timeframe	Notes
Section 10/Section 404 Permit	USACE	Y	12 to 18 months, depending on completion of Section 7 consultation	Locating a structure or excavating in navigable waters, or discharging dredged or fill material into waters of the United States
ESA Section 7 Concurrence	NOAA Fisheries	N	6 to 12 months	Will likely require a Biological Assessment given the presence of listed salmonids and designated critical habitat
EFH Concurrence	NOAA Fisheries	N		
NHPA Section 106 Concurrence	DAHP	N	3 to 6 months	If Federal nexus, DAHP and tribes must be consulted
State Water Reservoir Permit	Ecology	N	Within 2 years with expedited review	For constructing a barrier across a stream, channel, or water course if the barrier will create a reservoir to impound water
Dam Safety Construction Permit	Ecology	N	2 to 6 months, a larger or more complex project takes longer	For constructing, modifying, or repairing any dam or controlling works for storage of 10 or more acre-feet
Water Right	Ecology	N	1 to 2 years with expedited review	For new withdrawals from the Columbia River
Shoreline Substantial Development Permit	County	Y	2 to 3 months, and concurrent with USACE 404 permit process	According to the County Shoreline Master Program
Critical Areas Ordinance Compliance	County	Y	4 to 6 weeks	Per the County Critical Areas ordinance and Shoreline Master Program
Building, Fill, and Grade Permits	County	N	4 to 6 weeks	Required for structures, grading, and fill

Notes:

DAHP	Department of Archaeology and Historic Preservation (DAHP)
ESA	Endangered Species Act
EFH	Essential Fish Habitat
JARPA	Joint Aquatic Resources Permit Application
N	No
NHPA	National Historic Preservation Act
NOAA	National Oceanographic and Atmosphere Administration
Y	Yes
USACE	U.S. Army Corps of Engineers

U.S. Army Corps of Engineers Section 404/Section 10

The principal Federal laws that regulate activities in navigable waters and wetlands are Sections 404 and 401 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. A USACE permit is required when locating a structure, excavating, or discharging dredged or fill material in waters of the U.S., including wetlands, or transporting dredged material for the purpose of dumping it into marine waters. USACE also requires a permit for the activity of constructing a dam or impoundment in the bed of any stream, river, or wetland because it would require placement of fill material in a regulated water body. The timeframe for processing a complete project such as this would likely be 12 to 18 months.

6.1.1 ESA Section 7 Consultation (Biological Assessment)

The ESA identifies plant and animal species considered to be in danger of extinction (endangered) or likely to become endangered (threatened). The U.S. Fish and Wildlife Service (USFWS) administers the law for terrestrial plants and animals, and listed fish that do not migrate to the ocean. The ESA is also administered by the National Oceanic and Atmospheric Administration (NOAA) Fisheries for marine animals and anadromous fish that migrate from rivers to the ocean. USFWS and NOAA Fisheries are collectively referred to as “the Services” when ESA reviews are conducted. In this case, NOAA Fisheries would be involved because of the potential effects on the Columbia River anadromous species and a lack of evidence of listed terrestrial species in the project area.

Section 7 of the ESA is triggered when a Federal agency is involved. Federal involvement may take several forms, such as constructing a project, providing funds for project implementation, or having regulatory jurisdiction over a proposed action (i.e., issuing Federal permits). Federal agencies with one or more areas of involvement on the project as described above are required to consider the impacts of the proposed project on threatened and endangered species found in the project area.

The responsible Federal agency, also called the Action Agency, is required to document the degree to which the proposed project will impact any threatened or endangered species found in the project area. The agency then makes a determination of “no effect”, “not likely to adversely affect”, or “likely to adversely affect”.

"No Effect" Determination

A “no effect” determination is made when listed species will not be affected by the proposed action. This determination is made when the project actions would have no direct, indirect, or cumulative effects on listed species. For example, habitat will not be altered or the species is not found in the area at the time of year when the proposed activity will occur. A “no effect” determination is documented by the Federal Action Agency in a memorandum format and is generally not circulated to the Services.

"Not Likely to Adversely Affect" Determination

A determination of “not likely to adversely affect” is made when potential effects of the proposed action will be insignificant or unlikely to occur. Federal agencies prepare documents to describe the proposed project, project impacts, conservation measures, and the effects determination, which are submitted to the Services for review.

The Federal Action Agency prepares a Biological Evaluation (BE) to explain how the determination of “not likely to adversely affect” was made. The BE is circulated to the Services. The Services will then issue a letter of concurrence with the determination, or not concur. If a non-concurrence letter is sent, then the Services advise the Federal Action Agency to request formal consultation.

"Likely to Adversely Affect" Determination

If the Action Agency determines that a proposed project will result in significant environmental effects, a "likely to adversely affect" determination is made. This determination requires that a Biological Assessment (BA) be prepared. A BA is also prepared when the Action Agency has determined that a project may adversely affect a protected species.

In the case of a "likely to adversely affect" determination, the Action Agency requests a formal consultation with the Services. In response to this request, the Services prepare a BiOp, which first determines whether the adverse effects would jeopardize the continued existence of any species (jeopardy determination). If a jeopardy determination is made, the Services will identify reasonable and prudent alternatives (RPAs) that are intended to avoid jeopardy to the species. The Action Agency must implement these measures, or appeal to a higher authority. If jeopardy is not determined, then the Services will identify reasonable and prudent measures (RPMs), which the Action Agency must implement to reduce impacts to listed species. Jeopardy determinations are rare.

The ESA specifically mandates that the Section 7 process is strictly between the Services and the Action Agency; however, either the Action Agency or the Services can request input from others. The typical timeline for ESA consultation can be as brief as a month for "no effect" determinations, to 4 months and longer if the Services are required to prepare a BiOp, as would be required under a "likely to adversely affect" determination. The typical timeline for a "not likely to adversely affect" determination is 2 to 3 months.

Section 106 of the National Historic Preservation Act (NHPA) requires Federal agencies to take into account the effects of their undertakings on cultural resources (e.g., archaeological sites, historic buildings, and traditional cultural properties) and afford the Advisory Council of Historic Preservation (ACHP) a reasonable opportunity to comment on such undertakings. The Section 106 process seeks to accommodate historic preservation concerns with the needs of federal undertakings through consultation among agency officials and other parties with an interest in the effects of the undertaking on historic properties, commencing at the early stages of project planning. The goal of consultation is to identify historic properties potentially affected by the undertaking; assess its effect; and seek ways to avoid, minimize, or mitigate any adverse effects on historic properties.

Furthermore, cultural resources located on Federal property and on other lands involved in projects relying on Federal funding or permits are protected by both Federal and State law. State law protects archaeological sites and other cultural resources on private and State lands in Washington. Washington cultural resource law (Revised Code of Washington [RCW] 27.53) states that no known archaeological site or resource can knowingly be damaged without first obtaining a certified permit.

Multiple State and Federal jurisdictions could be participants in the Section 106 consultation process. Such participants might include the USACE, Confederated Tribes of the Umatilla Indian Reservation, Department of Archaeology and Historic Preservation (DAHP), and others. The duration of the Section 106 process could be 3 to 6 months, but could be longer for more complex projects.

6.1.2 National Environmental Policy Act

NEPA applies to Federal projects, any project requiring a Federal permit, and projects receiving Federal funding. NEPA requires the Action Agency to inform the public of potential environmental, social, and economic effects, and to solicit and consider public comments. This environmental review is used to clearly document potential environmental impacts of proposed alternatives so that environmental considerations are taken into account in project selection.

NEPA review is likely to be required when any action is proposed that requires a Federal agency to implement, fund, or approve (e.g., issue a Federal permit) a proposed action. If a project receives Federal funding, then NEPA review will be required. An EIS is required when a project is likely to have significant adverse impacts on the environment. The EIS is intended to help agency decision makers, applicants, and the public understand how a proposal will affect the environment by providing an objective discussion of significant environmental impacts, reasonable alternatives, and measures to avoid or minimize adverse impacts. NEPA review may identify issues that could lead to the selection of a no-action alternative.

Potential lead agencies for this project could be the USACE for Section 404, NMFS for Section 7, or, if applicable, any agency providing federal funding.

6.1.3 State Environmental Policy Act

SEPA was enacted by the Washington State Legislature to ensure that State and local agencies consider likely environmental consequences of all government decisions or “actions.” These decisions or actions may include issuing permits; adopting regulations, policies, or plans on private lands; or constructing public facilities on private State or local municipal lands.

If a project is likely to have significant adverse impacts on the environment, an EIS is required. The EIS is intended to help agency decision makers, applicants, and the public understand how a proposal will affect the environment by providing an objective discussion of significant environmental impacts, reasonable alternatives, and measures to avoid or minimize adverse impacts. SEPA and NEPA requirements can be met through a single environmental review process and EIS document.

6.1.4 Water Quality Certification (Section 401)

Ecology administers this program with delegated authority from the Federal government. A Water Quality Certification (Certification) is required of any applicant for a Federal license or permit to conduct any activity that may result in any discharge into surface waters. This includes discharge of dredge and fill material into water or wetlands. The Federal agency is provided a certification from the state that the discharge complies with the discharge requirements of Federal law and the aquatic protection requirements of State law. The timing of certification is tied to the USACE Section 404 permit applications. Public notice for a water quality certification may occur along with the USACE public notice.

6.1.5 National Pollutant Discharge Elimination System

As authorized by the Clean Water Act, the NPDES permit issued by Ecology is required when construction activities disturb a threshold land area of 1 acre or more.

6.1.6 Hydraulic Project Approval/Joint Aquatic Resource Permit Application

Any form of work that uses, diverts, obstructs, or changes the natural flow or bed of any fresh water of the state requires a Hydraulic Project Approval (HPA) from the WDFW. A complete application package for a HPA must include a completed Joint Aquatic Resource Permit Application (JARPA) form, general plans for the overall project, and complete plans and specifications of the proposed work within waters of the State. A JARPA can be used to apply for HPAs, shoreline management permits, water quality certifications, and USACE Section 404 and Section 10 permits. The application also must include plans for the protection of fish life.

6.1.7 Reservoir Storage Permit

Ecology has jurisdiction of all reservoirs with storage capacities greater than 10 acre-feet. A Reservoir Storage Permit will be required before construction of the reservoir to allow for the diversion and storage of water.

6.1.8 Dam Construction Permit

Ecology has jurisdiction of all reservoirs with storage capacities greater than 10 acre-feet. A Dam Construction Permit will be required before construction of the reservoir. Application for a Dam Construction Permit requires review of design calculations by Ecology's DSO. Required calculations and documentation include detailed dam design and embankment calculations, detailed spillway sizing and design calculations, detailed inlet/outlet works design calculations, and evaluation of potential downstream hazard including a dam failure inundation analysis.

6.1.9 Water Right/Permit

A water right permit is applied for in coordination with the Reservoir Storage Permit (see Section 6.1.9). Ecology has jurisdiction for public waters of the State, including the Columbia River. Ecology has an expedited permitting review process that could be used to secure a water permit for storage, along with Ecology authority through the Columbia River program to develop projects that provide both in and out of stream benefits. The Switzler Reservoir storage project is consistent with these objectives.

6.1.10 County Shorelines Management Act Permit (Shoreline Substantial Development or Conditional Use Permit)

These permits are required for development located on a State water or shoreline area. Waters of the State include the Columbia River, which is also considered a shoreline of statewide significance. The JARPA permitting process described above can be used to address the SMP requirements.

6.1.11 Critical Areas Review

Benton County must complete a critical areas review to determine if there are any potential effects to wetlands, fish and wildlife habitat conservation areas, geologic hazards, or frequently flooded areas. This review would include the application of conditions to protect the functions and values of applicable critical areas in the project area. The County will accept reports and applications addressing other State and Federal requirements as acceptable documentation for completing the critical areas review to verify compliance with County's Critical Areas Ordinance (Ben Floyd personal communication with Clark Posey, Benton County Planning Department on December 6, 2012).

6.1.12 Building, Fill and Grading Permits

Benton County has a building permit application that must be completed for electrical and other structures, and for project fill and grading requirements. The County will accept reports and applications addressing other State and Federal requirements as acceptable documentation for attachments to the building permit application.

6.2 Permitting Strategy

In securing Federal, State, and county permits for this project, early informal consultation with the Federal and State permitting agencies and Tribes is critical. This is particularly important for discussing the suggested mitigation and habitat enhancement strategies identified to offset project impacts. Obtaining input from these agencies and the Tribes early in the design process can ensure that environmental objectives and permitting requirements are designed in from the beginning of the project, helping to avoid redesign costs.

In these communications, it is important to state the project purposes and benefits. The Switzler Canyon dam project has both water supply and Columbia River instream flow benefits and this information should be shared, along with contextual information on the project location and the existing habitat functions and conditions.

Central to the permitting strategy will be preparing the NEPA/SEPA EIS. Because the project would likely include non-exempt SEPA actions in both Benton and Klickitat Counties, it was presumed a co-SEPA lead permitting strategy for an EIS would likely occur. Through the preparation of this document, the project proponent can incorporate information that addresses most of the specific permitting requirements as outlined in Table 6-1. Benton/Klickitat Counties can rely on the EIS and associated technical documents to meet most if not all local permitting requirements, with supplemented information as necessary to address specific local provisions (Ben Floyd personal communication with Clark Posey, Benton County Planning Department on December 6, 2012).

When Benton/Klickitat Counties pursue this NEPA-integrated permitting strategy, the focus will be on confirming and analyzing water resources and biological effects early in the process and sharing this information with regulatory agencies. Addressing these effects and obtaining concurrence on mitigation and enhancement activities are often what dictate the overall permitting compliance schedule. Overall project environmental review and permitting on this project will likely take 2.5 to 3.5 years, assuming available funding is dedicated early in the process to address these requirements, and the information needed to address permitting requirements is developed during environmental review with permit applications submitted shortly after the EIS process is completed.

6.3 Permitting Conclusions

This environmental resources and permitting requirements fatal flaws analysis is intended to assess the potential for issues that would inhibit the project from obtaining needed permits and approvals. Based on this preliminary assessment, there are no known existing conditions that would inhibit obtaining permits for construction and operation of the project as long as appropriate avoidance, minimization, and mitigation measures were employed to offset potential natural resource impacts. A more detailed environmental review and evaluation of permit requirements is recommended as part of a detailed feasibility study for the Switzler Reservoir project.

7 Summary and Recommendations

This report concludes at a preliminary level that a new Columbia River off-channel storage reservoir could be constructed in Switzler Canyon with a peak storage capacity of approximately 44,000 acre-feet through construction of a concrete-faced rockfill dam approximately 325 feet in height. Water would be delivered to the reservoir from the Columbia River during periods when water is available, which is limited during dry water years and some months of average years. The maximum new mitigated supply that could be made available by the project was estimated assuming that at least 75% of the annual supply would be available with 100% reliability and that the total annual supply would be available with 90% reliability (9 out of 10 years). If a 200-cfs pump station is constructed to fill the proposed reservoir, it is estimated that 41,080 acre-feet of new mitigated supply could be developed with 91% reliability. In 9% of years, newly generated mitigated supply would be limited; however, the project would supply 30,800 acre-feet (75% of supply) with 100% reliability. In wet years, the full reservoir capacity of 44,000 acre-feet could be stored and used.

At this appraisal phase of the project, the Switzler Reservoir project would include the follow major construction elements:

- A 200-cfs pump station on the Columbia River adjacent to the existing agricultural pump station at the mouth of Switzler Canyon;
- A 325-foot-tall rockfill dam to create a 44,000 acre-foot storage reservoir;
- An emergency side-channel spillway and common inlet/outlet works at the proposed dam;
- A low-level outlet to Switzler Canyon at the downstream toe of the dam;
- 5,800 linear feet of 84-inch diameter, welded-steel inlet/outlet pipeline;
- An 84-inch-diameter outfall to discharge reservoir water to the Columbia River; and
- Improvements to the Switzler Canyon stream channel downstream of the reservoir to improve conveyance conditions, reduce erosion potential, and mitigate for aquatic habitat impacts.

Additional improvements would also be undertaken to mitigate for environmental impacts.

The estimated capital cost for project construction is $281 million, which equates to a cost of $13 million or $318 per acre-foot when amortized annually. Annual O&M costs are estimated at $4.5 million or $109 per acre-foot. Total cost per acre-foot for new mitigated supply is therefore $427 per acre-foot. Based upon preliminary benefit-cost analysis, a substantial portion of these costs may be justifiable for funding through State, Federal or local sources, including local match requirements. The likely future uses of the new water supply would be expansion of high-value irrigated crops and supplying municipal purveyors.

The proposed reservoir will require the acquisition of a variety of permits from local, State and Federal agencies, including a full suite of aquatic permits pursuant to the Clean Water Act and ESA. The project will require SEPA (and likely NEPA) review. Based upon preliminary assessments of this project, there are no known existing conditions that would inhibit obtaining necessary permits provided adequate mitigation measures are implemented.

The recommended next steps for the project would include securing funding for preparation of the NEPA/SEPA review (EIS), addressing most of the specific permitting requirements for this project, followed by a detailed feasibility study, including site-specific data collection supporting design. It is anticipated that the overall project environmental review and permitting for this project would likely take up to 3.5 years with design and construction requiring approximately 5 years.

8 References

Aspect Consulting and Anchor QEA, 2010. Water Storage Pre-feasibility Assessment Report, Horse Heaven Area, WRIA 31. Prepared for the WRIA 31 Planning and Advisory Committee in Association with Anchor QEA, LLC. October 27, 2010.

Aspect Consulting and Anchor QEA, 2012. Phase 1 Report: Horse Heaven Water Storage Appraisal Assessment, WRIA 31. Prepared for the WRIA 31 Planning and Advisory Committee in Association with Anchor QEA, LLC. August 15, 2012.

Ecology, 2009. Dam Safety Guidelines, Technical Note 3: Design Storm Construction. Prepared by Department of Ecology Dam Safety Office. Revised October 2009. Publication #92-55G.

Ecology, 2011. 2011 Technical Report for the Columbia River Basin Long-Term Water Supply and Demand Forecast. Prepared by Washington State University. Ecology Publication No. 12-12-001.

Ben Floyd personal communication with Clark Posey, Benton County Planning Department on December 6, 2012

Ben Floyd and Ryan Brownlee, personal communications with Dale Shelton on November 6, 2012.

Hamlet, A.F., P. Carrasco, J. Deems, M.M. Elsner, T. Kamstra, C. Lee, S-Y Lee, G. Mauger, E. P. Salathe, I. Tohver, L. Whitely Binder, 2010, Final Project Report for the Columbia Basin Climate Change Scenarios Project, http://www.hydro.washington.edu/2860/report/.

National Marine Fisheries Service (NMFS), 2010. Endangered Species Act Section 7(a)(2) Consultation Supplemental Biological Opinion. Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(I)(A) Permit for Juvenile Fish Transportation Program.

NOAA, 1994. Hydrometeorological (HMR) Report No. 57, Probable Maximum Precipitation – Pacific Northwest States. Columbia River (including portions of Canada), Snake River, and Pacific Coastal Drainages. Prepared by E.M. Hansen, D.D. Fenn, P. Corrigan, and J.L. Vogel, Water Management Division, Office of Hydrology, National Weather Service, in Association with L.C. Schreiner and R.W. Stodt, Flood Section, Surface Water Branch, Earth Sciences Division, Bureau of Reclamation. October 1994.

Schuster, J.E., 1994, Geologic Maps of the East Half of the Washington Portion of the Goldendale 1:100,000 Quadrangle and the Washington Portion of the Hermiston 1:1,00,00 Quadrangle, Washington Division of Geology and Earth Resources, Open File Report 94-9, June 1994.

U.S. Bureau of Reclamation, 1987. Design of Small Dams. Prepared by the U.S. Bureau of Reclamation. Third Edition, 1987.

USGS, 2012. http://water.usgs.gov/osw/streamstats/. USGS Web-based Integrated GIS Application for Streamflow Statistics.

Washington Division of Geology and Earth Resources (WDGER), 2012, Washington Interactive Geologic Map, https://fortress.wa.gov/dnr/geology/?Site=wigm.

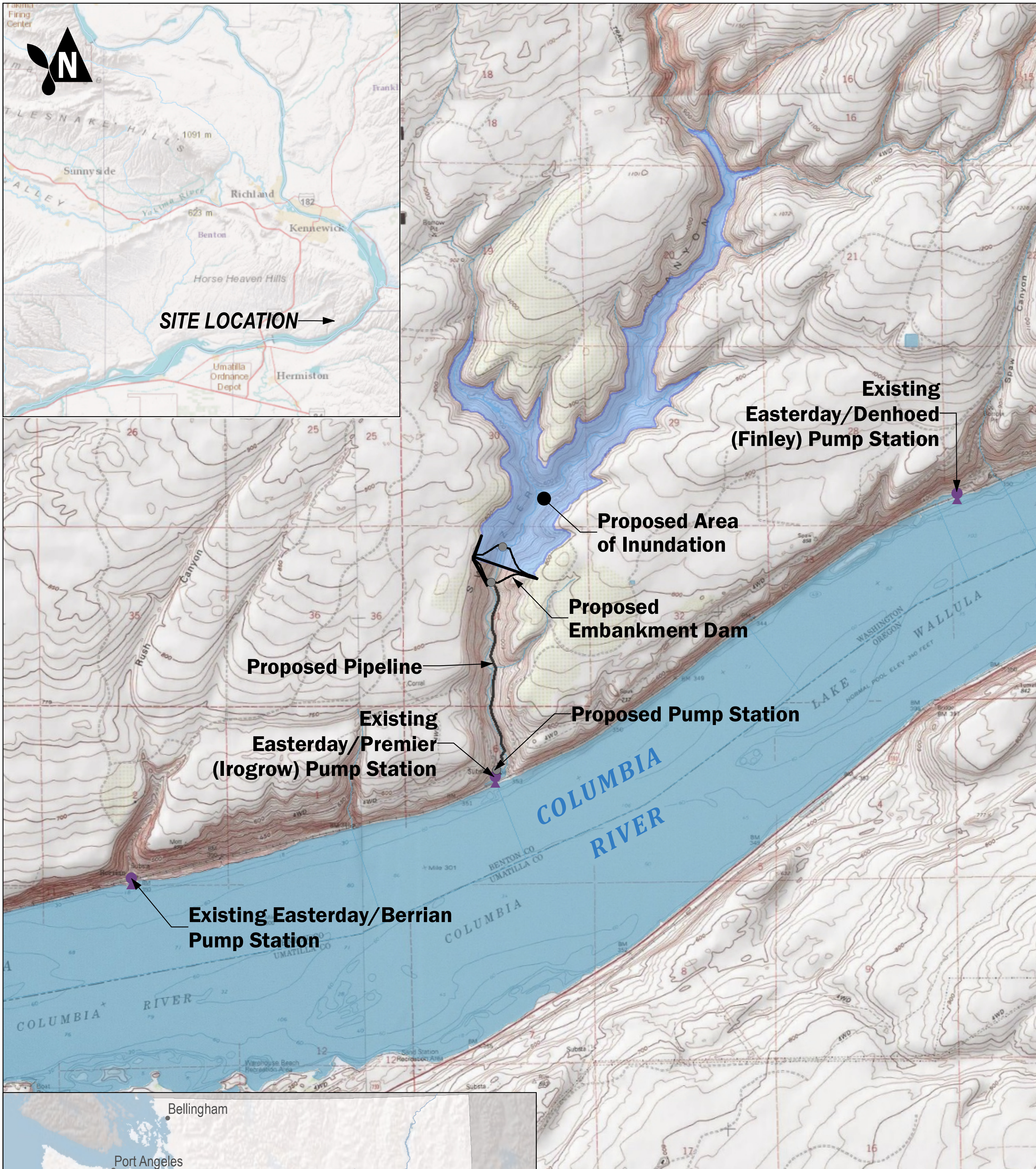
Watershed Professionals Network (WPN), 2009. WRIA 31 Instream Habitat Assessment. Prepared for Klickitat County and Department of Ecology Shorelines and Environmental Assistance Program. July 31, 2009.

Washington State Conservation Commission (WSCC), 2001. Salmonid Habitat Limiting Factors, Water Resource Inventory Area 32, Walla Walla Watershed. April 1, 2001.

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting are intended solely for the Client and apply only to the services described in the Agreement with Client. Any use or reuse by Client for purposes outside of the scope of Client's Agreement is at the sole risk of Client and without liability to Aspect Consulting. Aspect Consulting shall not be liable for any third parties' use of the deliverables provided by Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

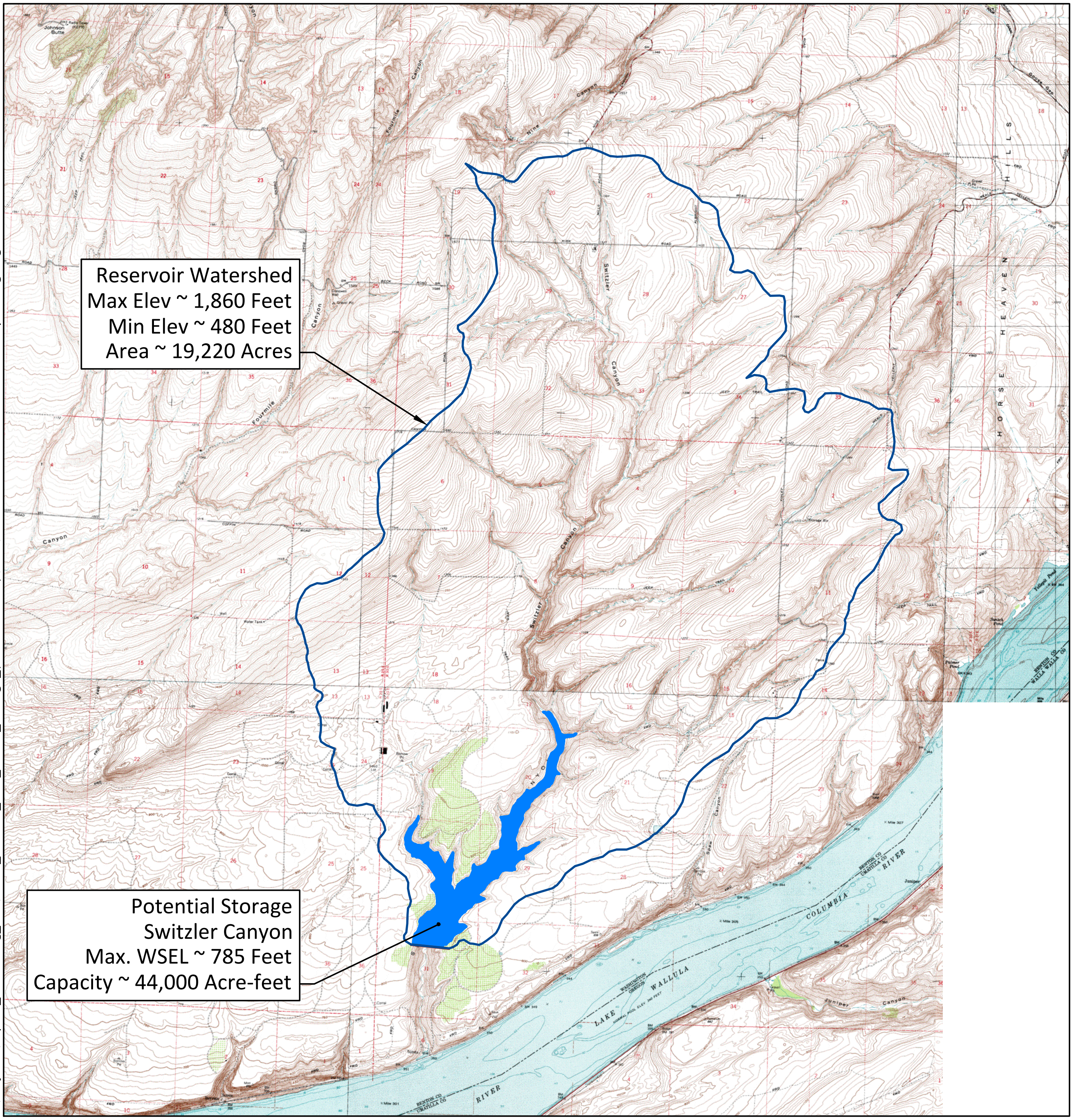


Project Vicinity

Horse Heaven Water Storage Appraisal Assessment
Refined Engineering and Cost Estimate
WRIA 31, Washington

Aspect CONSULTING | ANCHOR QEA | BY: JRB / EAH | DEC-2012 | PROJECT NO. 090045 | FIGURE NO. 2-1

GIS Path: T:\projects_8\WRIA31HHH_CSM-090045-04-10\Working\Dec2012\Fig1_ProjectVicinity.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 12/20/2012 || User: hlovelace || Print Date: 12/20/2012



SOURCE: 100,000 USGS topographical map

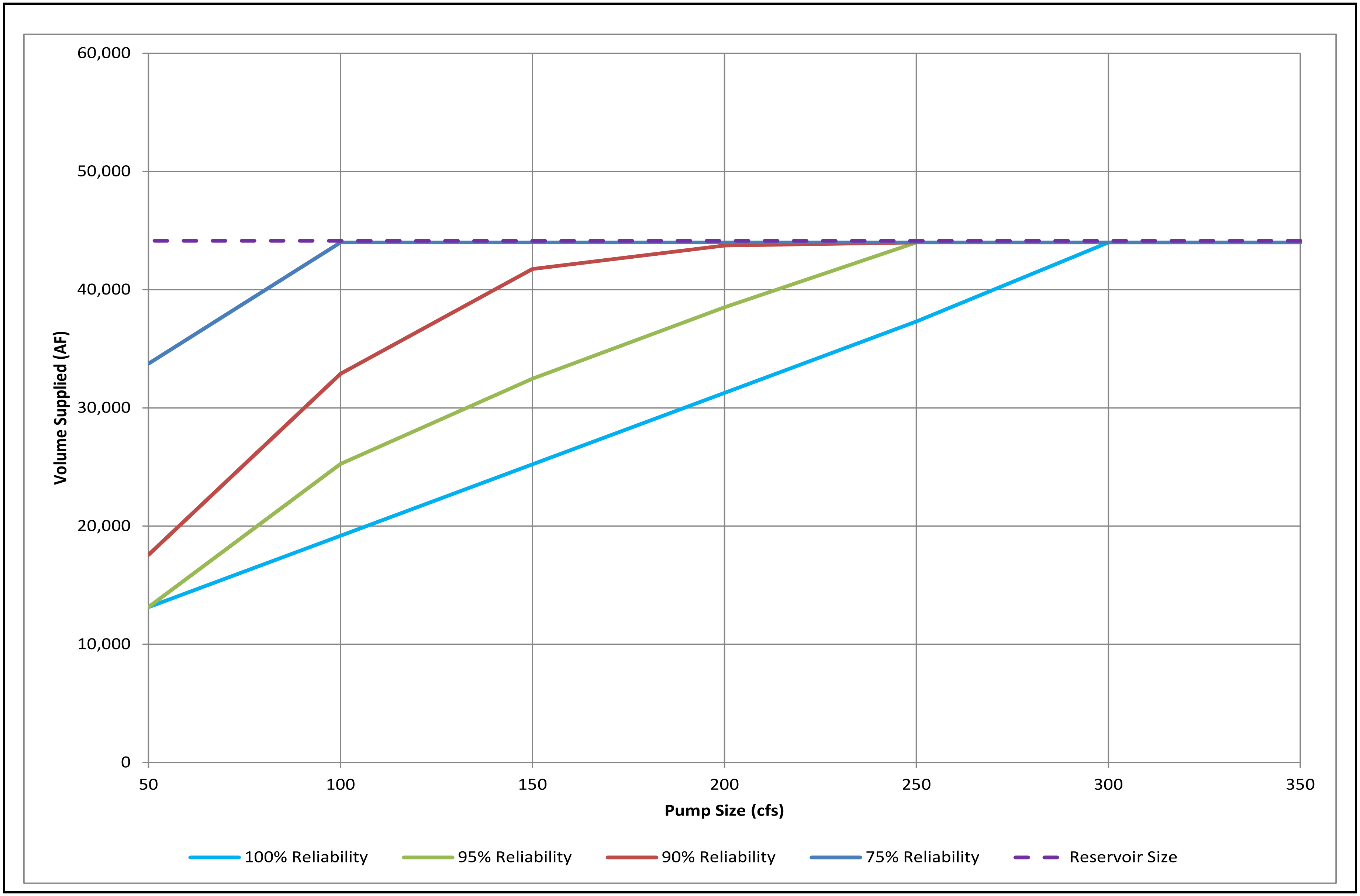
HORIZONTAL DATUM: UTM Zone 11, NAD 27

VERTICAL DATUM: NGVD 29

0 8,000
Scale in Feet

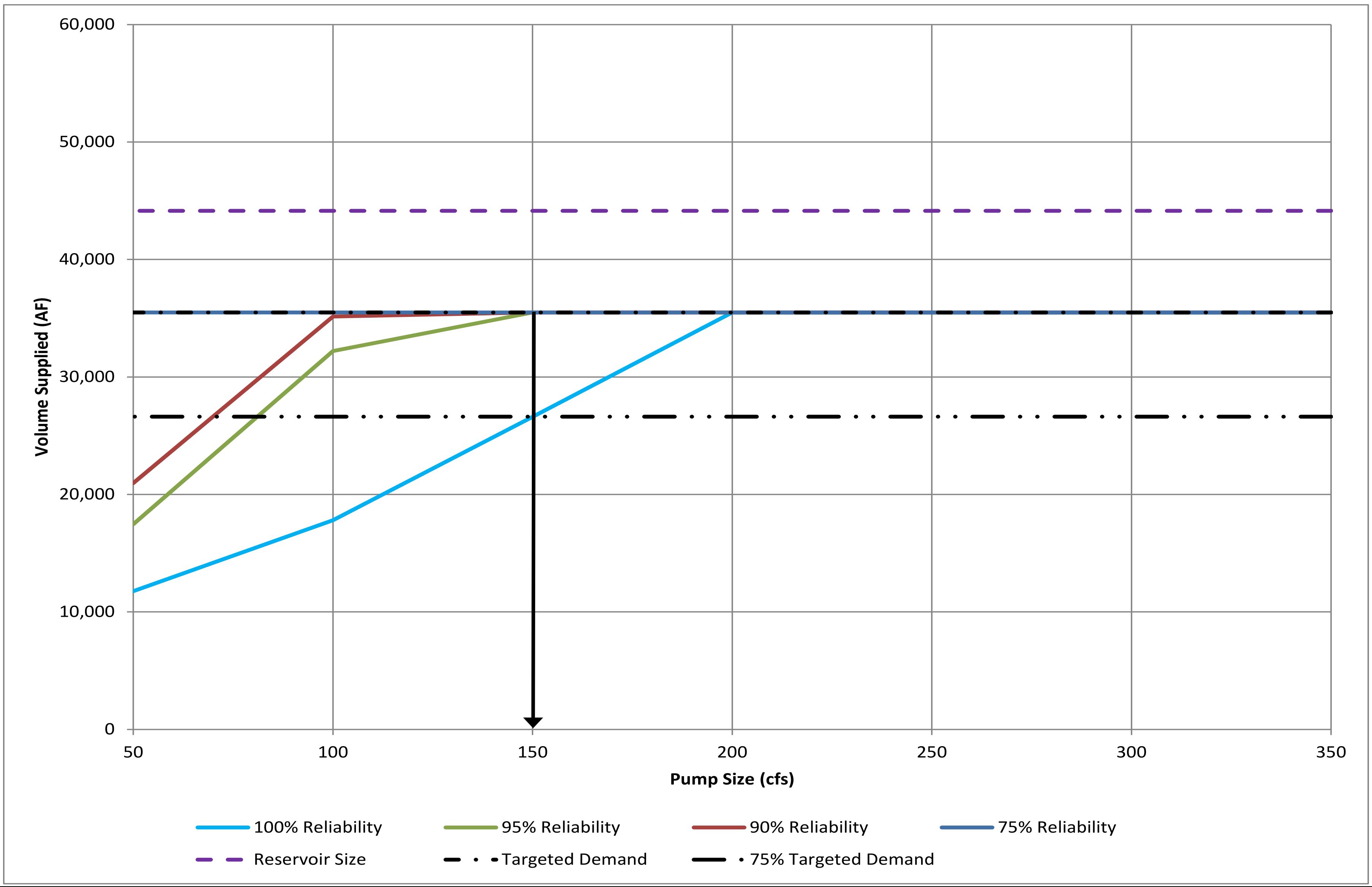
Figure 2-2
Switzler Canyon Reservoir Watershed
Phase II Report
Horse Heaven Water Storage Appraisal Assessment

ANCHOR QEA



ANCHOR QEA

Figure 3-1
Annual Reliability, Existing Conditions, Target Demand of 44,000 Acre-feet
Phase II Report
Horse Heaven Water Storage Appraisal Assessment



ANCHOR QEA

Figure 3-2
Annual Reliability, Existing Conditions, Target Demand of 35,480 Acre-feet
Phase II Report
Horse Heaven Water Storage Appraisal Assessment

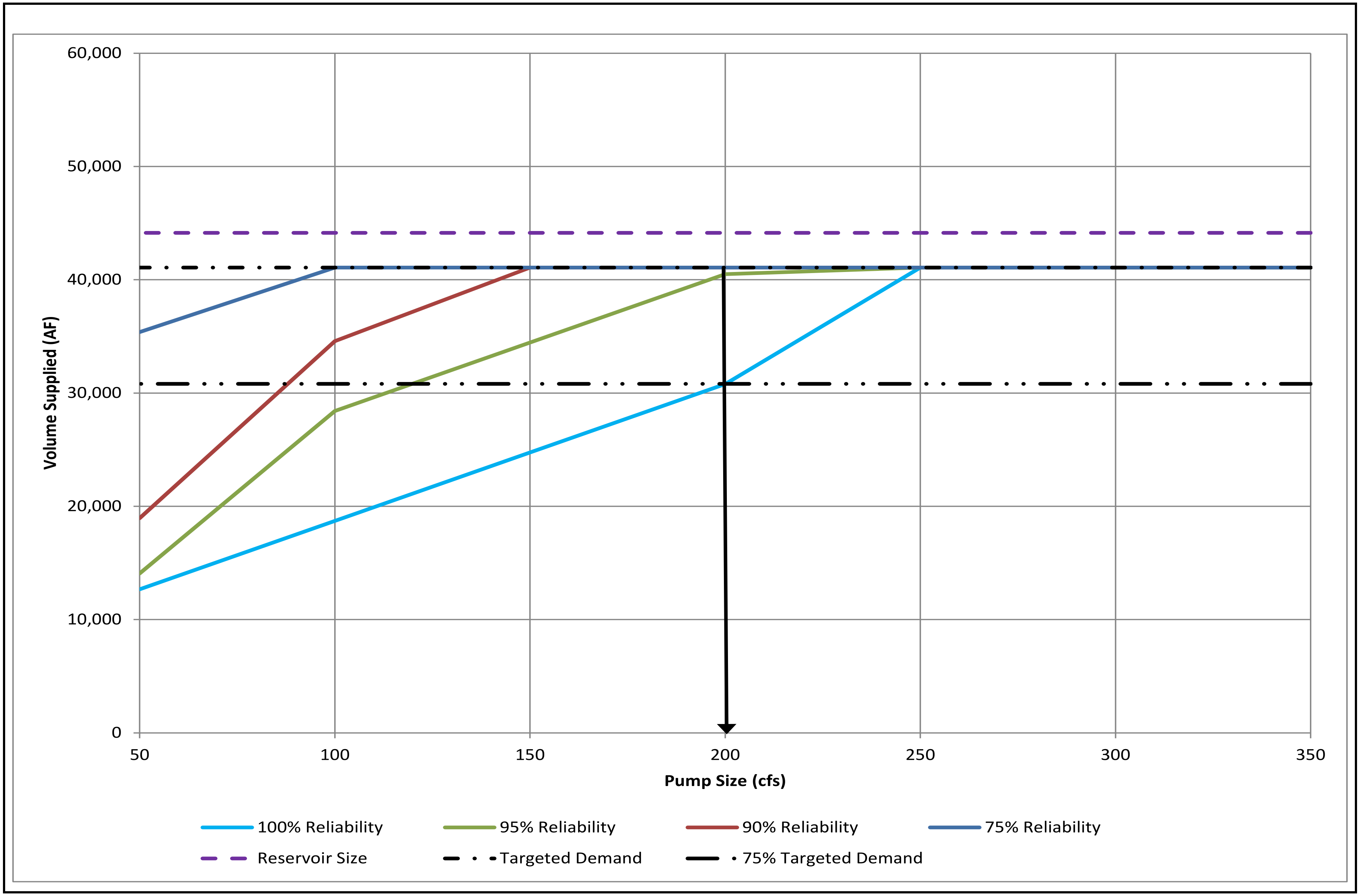


Figure 3-3
Annual Reliability, Existing Conditions, Target Demand of 41,080 Acre-feet
Phase II Report
Horse Heaven Water Storage Appraisal Assessment

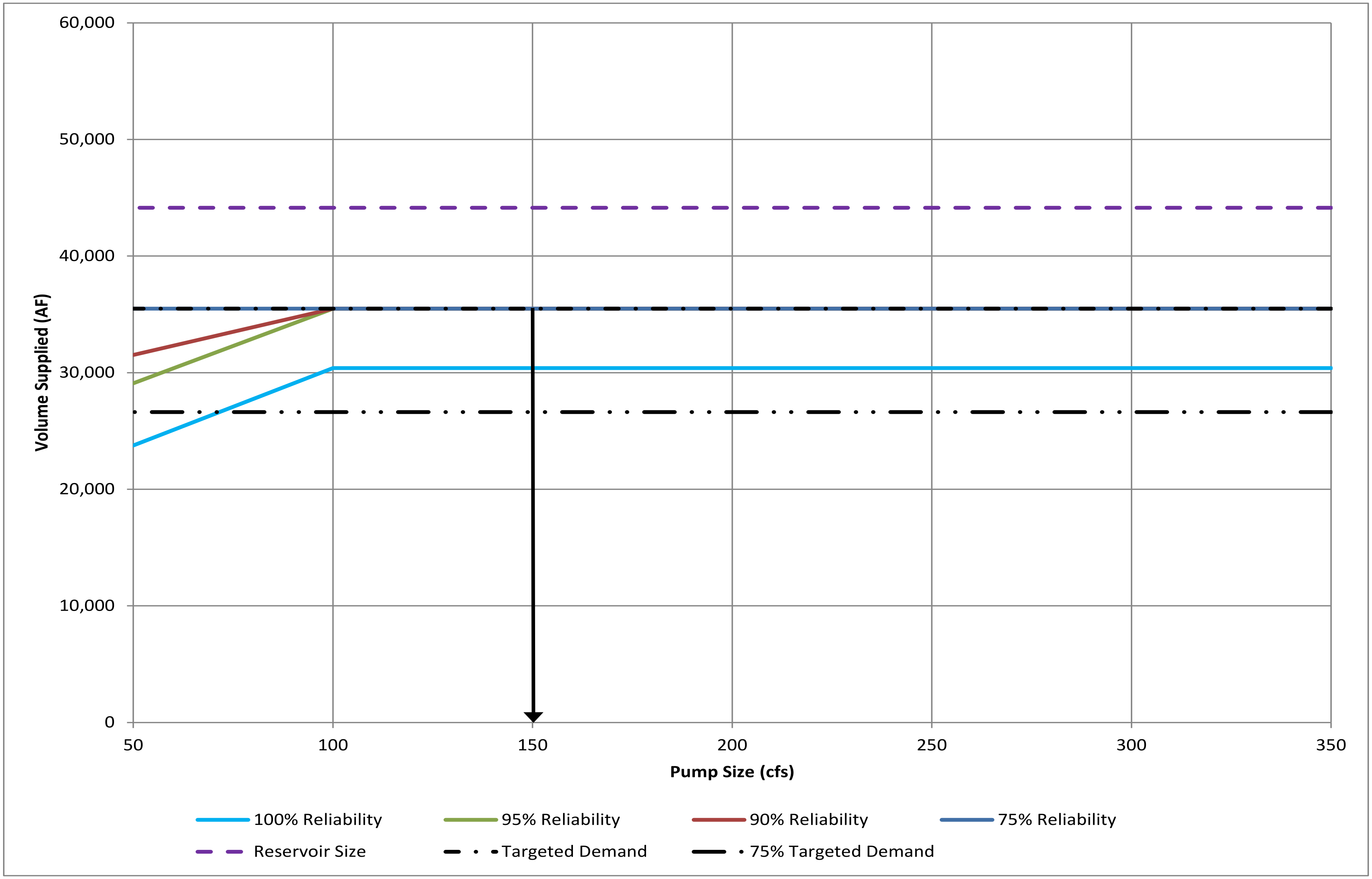
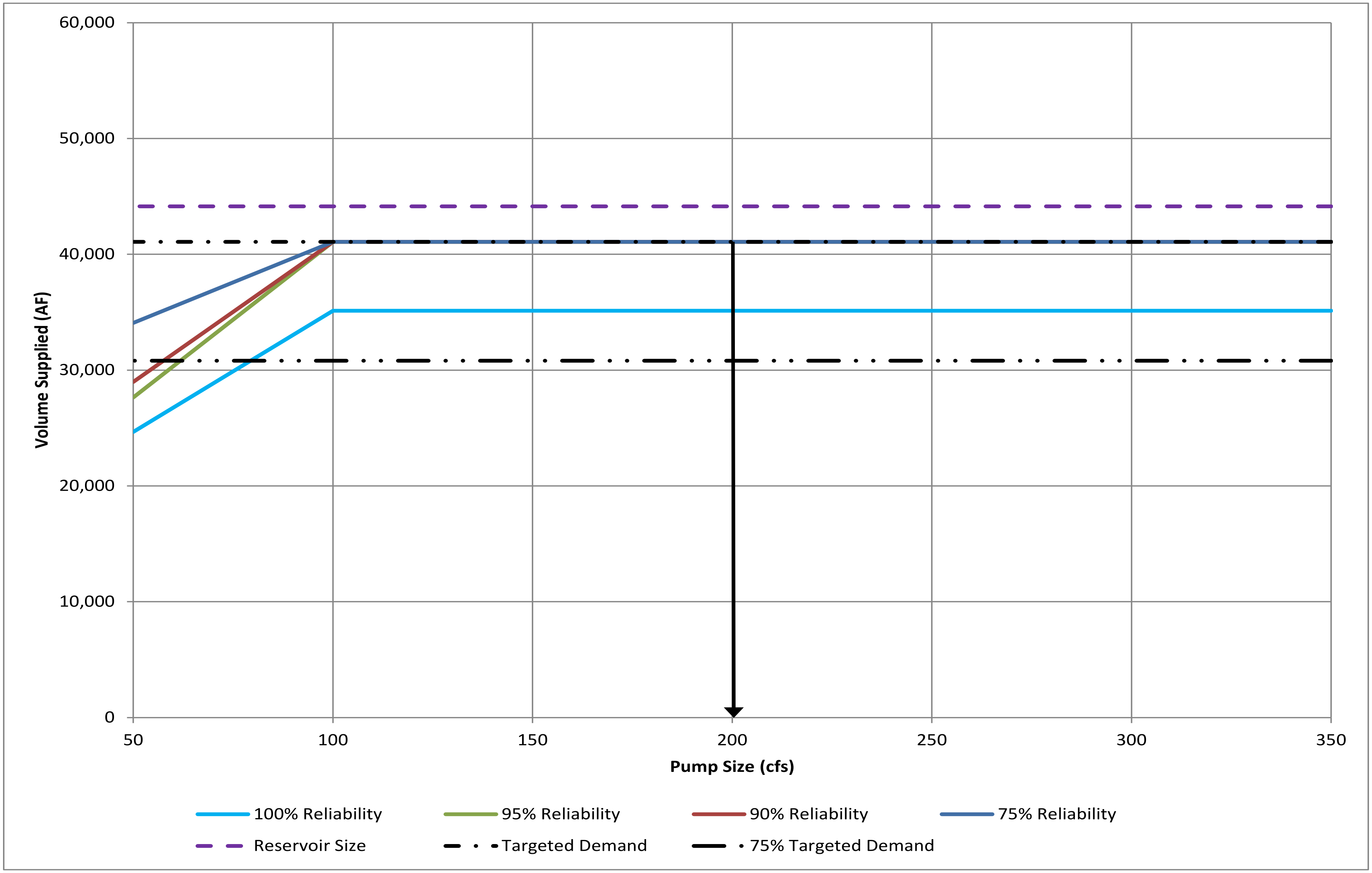


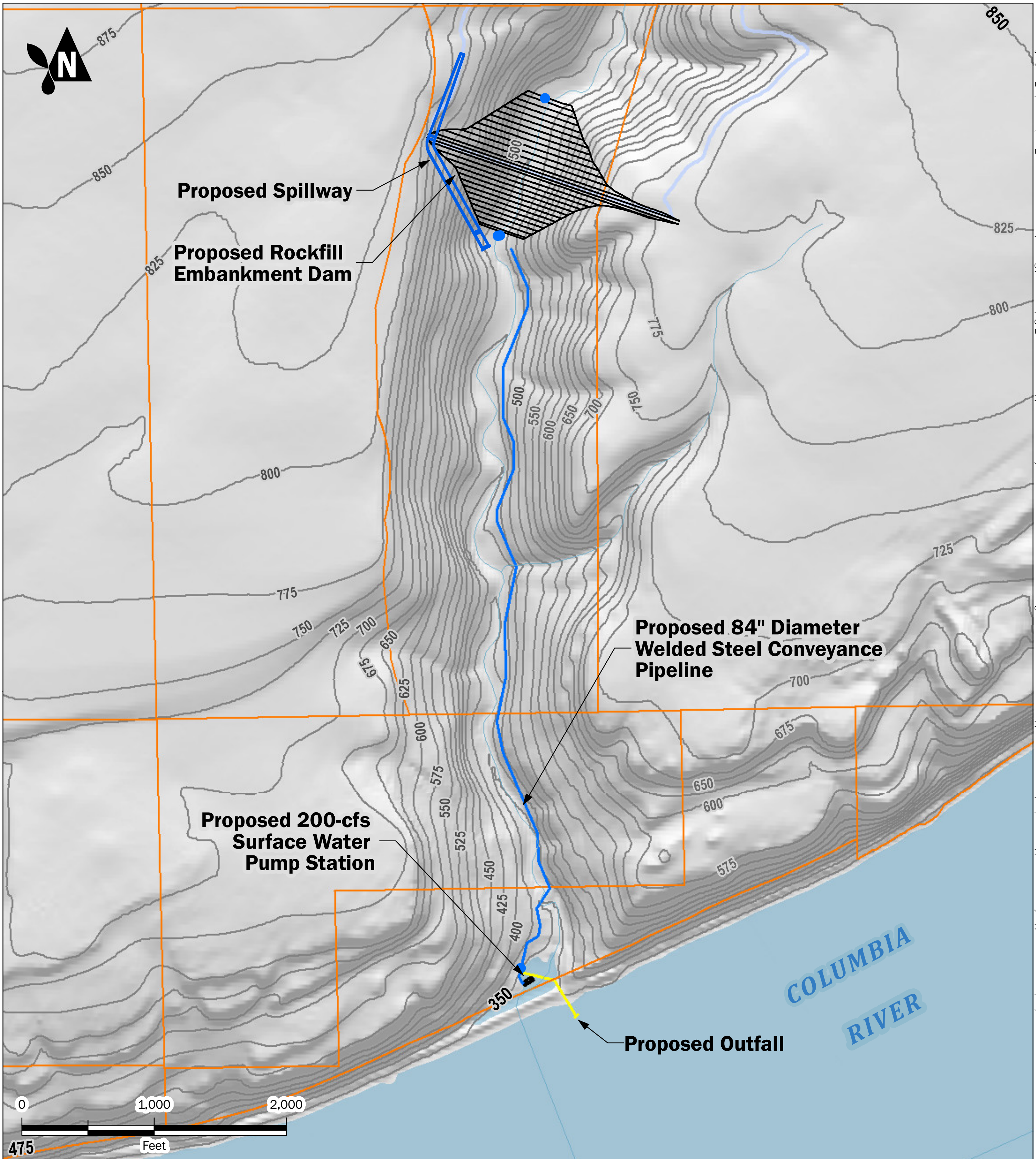
Figure 3-4
Annual Reliability, Future Conditions, Target Demand of 35,480 Acre-feet
Phase II Report
Horse Heaven Water Storage Appraisal Assessment



L:\Projects\Aspect_Consulting_LLC\Horse_Heaven_Hills_Water_Storage_(110204-02.01)\Reports\Figure3-5.docx

ANCHOR QEA

Figure 3-5
Annual Reliability, Future Conditions, Target Demand of 41,080 Acre-feet
Phase II Report
Horse Heaven Water Storage Appraisal Assessment



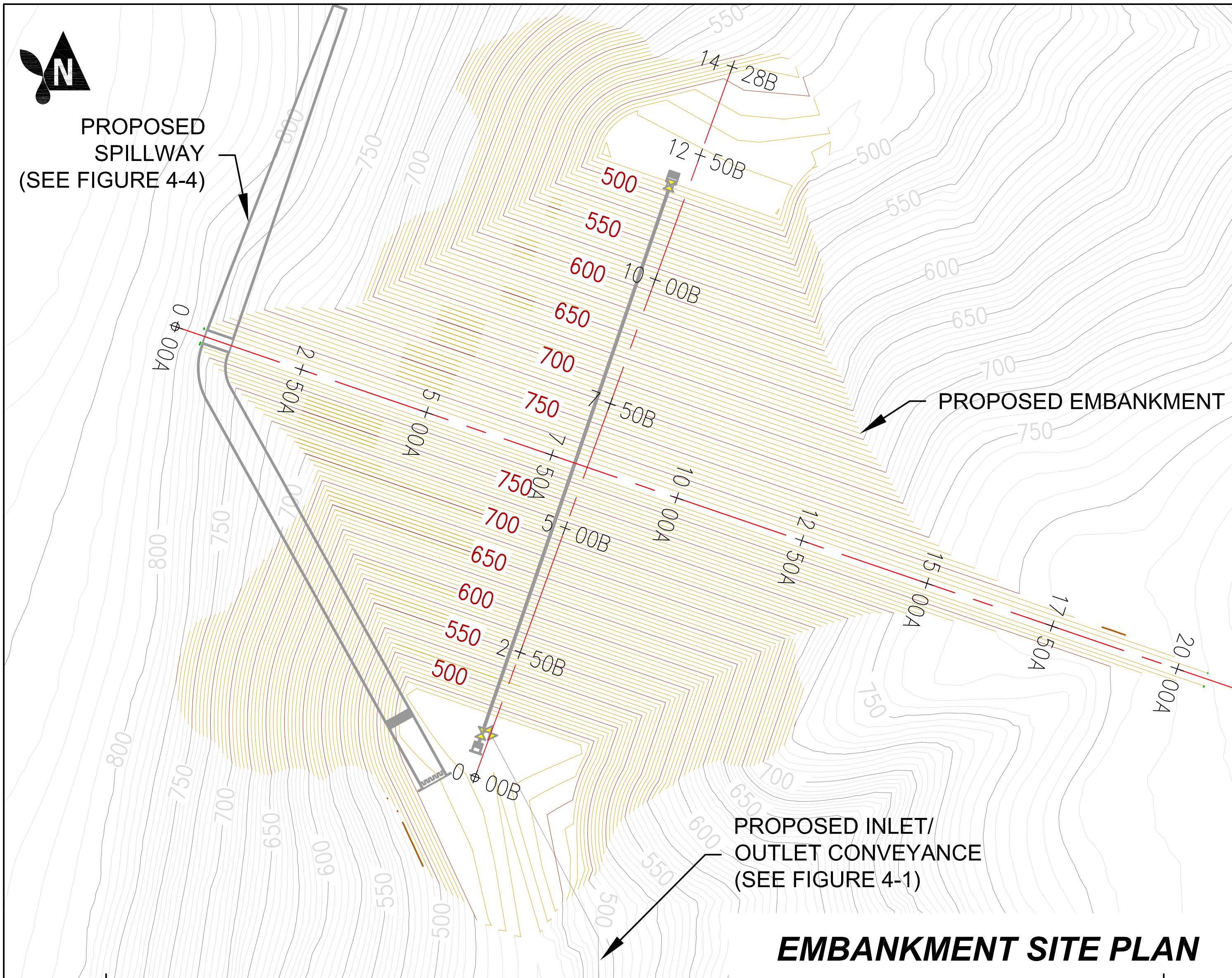
Proposed Pipeline
25-foot Contour
Feature
Parcel
Reservoir
Proposed Spillway
Proposed Rockfill Embankment
Proposed Outfall
Watercourse
Waterbody

Site Plan

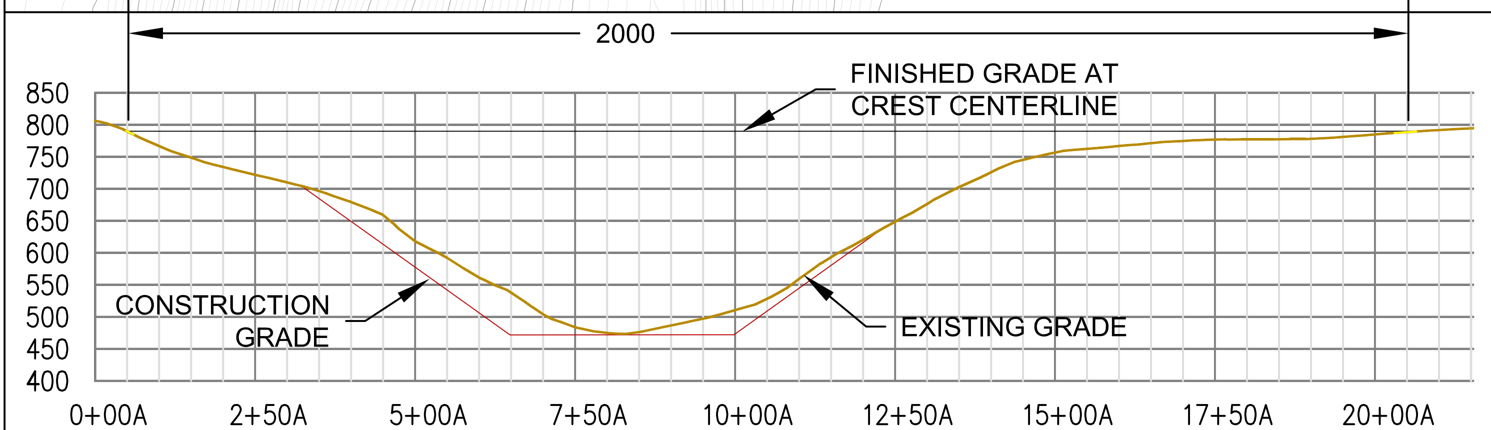
Horse Heaven Water Storage Appraisal Assessment
Refined Engineering and Cost Estimate
WRIA 31, Washington

Aspect CONSULTING | ANCHOR QEA | BY: JRB / EAH | DEC-2012 | PROJECT NO. 090045 | FIGURE NO. 4-1

GIS Path: T:\projects_8\WRIA31HHH_CSM-090045-04-10\Working\Dec2012\Fig2_SitePlan.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 12/19/2012 || User: ehealy || Print Date: 12/19/2012



EMBANKMENT SITE PLAN



EMBANKMENT SECTION

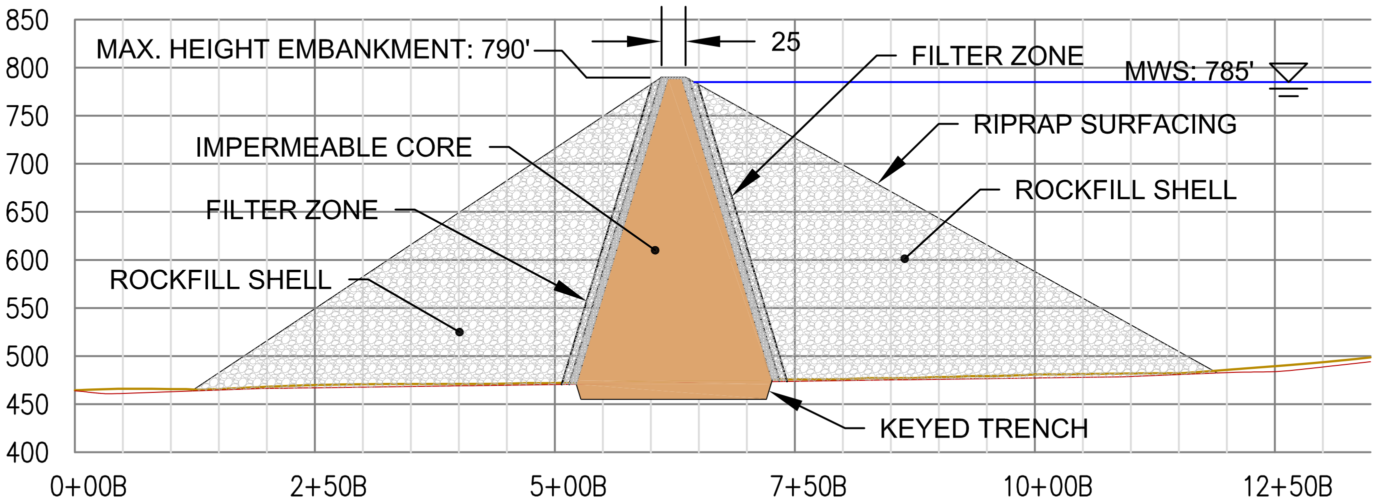
NOTE: SPILLWAY AND INLET/OUTLET NOT SHOWN THIS VIEW

0 300 600
Feet

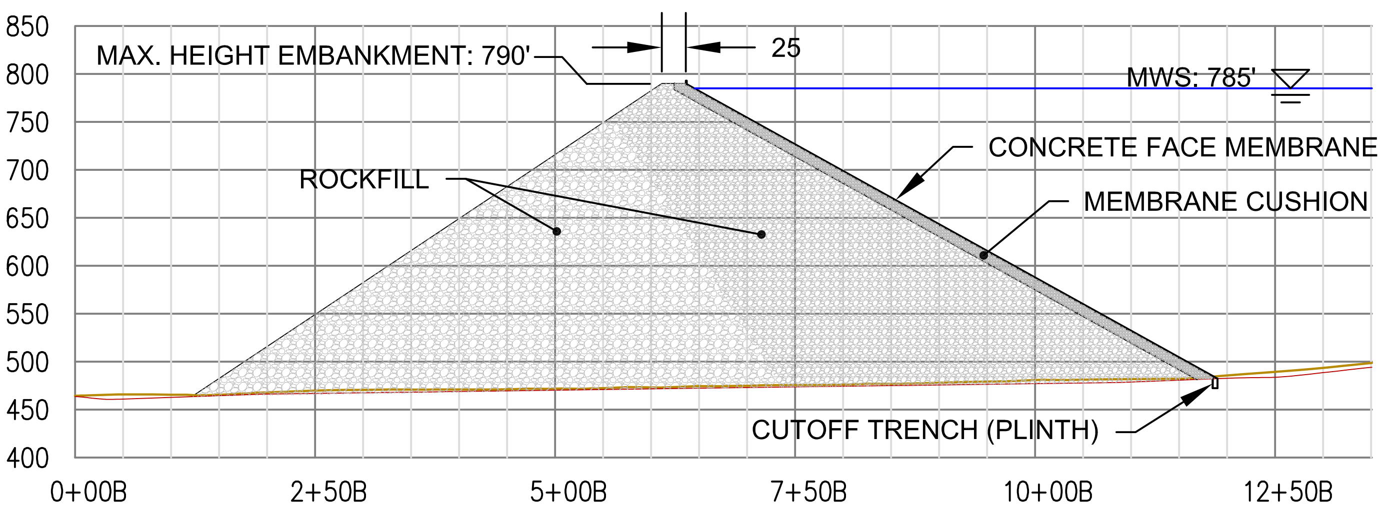
Embankment
Conceptual Site Plan and Section
Horse Heaven Water Storage Appraisal Assessment
Refined Engineering and Cost Estimate
WRIA 31, Washington

Aspect CONSULTING	Dec-2012	BY: JRB/JLP	FIGURE NO.
	PROJECT NO. 090045	REV BY: -	4-2

CAD Path: Q:\WRIA\030009 WRIA 31\Switzler Reservoir\Figure 4-2 and 4-3 - Embankment.dwg Figure Y || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Dec 19, 2012 9:09am || User: rbrownlee



ZONED ROCKFILL ALTERNATIVE
(IMPERMEABLE CORE)



DECKED ROCKFILL ALTERNATIVE
(UPSTREAM CONCRETE FACE)

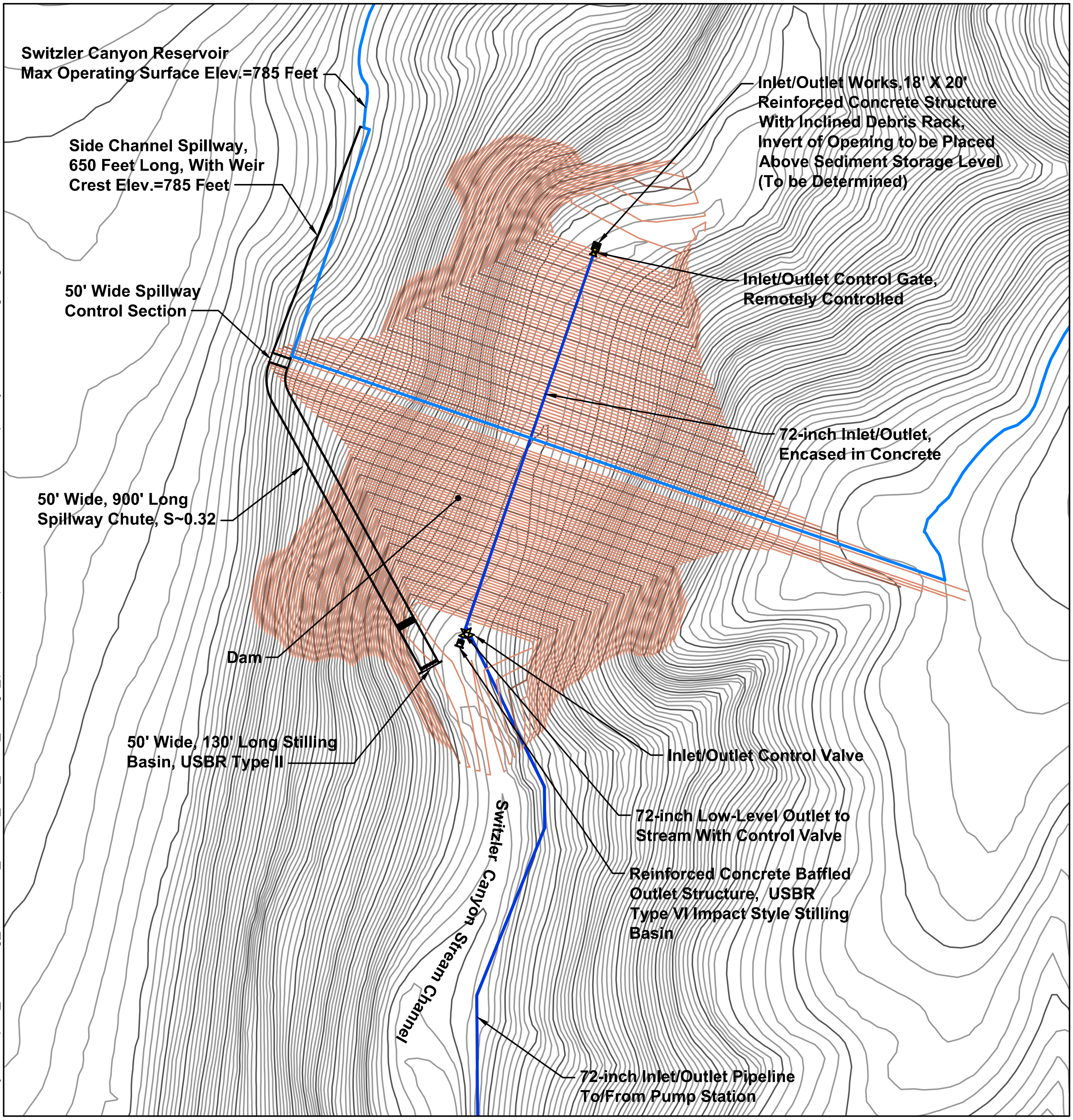
EMBANKMENT SECTIONS

0 200 400
Feet

Embankment
Conceptual Section Alternatives
Horse Heaven Water Storage Appraisal Assessment
Refined Engineering and Cost Estimate
WRIA 31, Washington

Aspect CONSULTING	Dec-2012	BY: JRB/JLP	FIGURE NO.
	PROJECT NO. 090045	REV BY: -	4-3

CAD Path: Q:\WRIA\030009 WRIA 31\Switzler Reservoir\Figure 4-2 and 4-3 - Embankment.dwg Figure X || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Dec 19, 2012 9:11am || User: rbrownlee



L:\Projects\Aspect_Consulting_LLC\Horse_Heaven_Hills_Water_Storage_(110204-02.01)\CAD\WRIA 31 - Switzler Spillway and Outlet.dwg Figure 4-4

Dec 20, 2012 8:43am drice

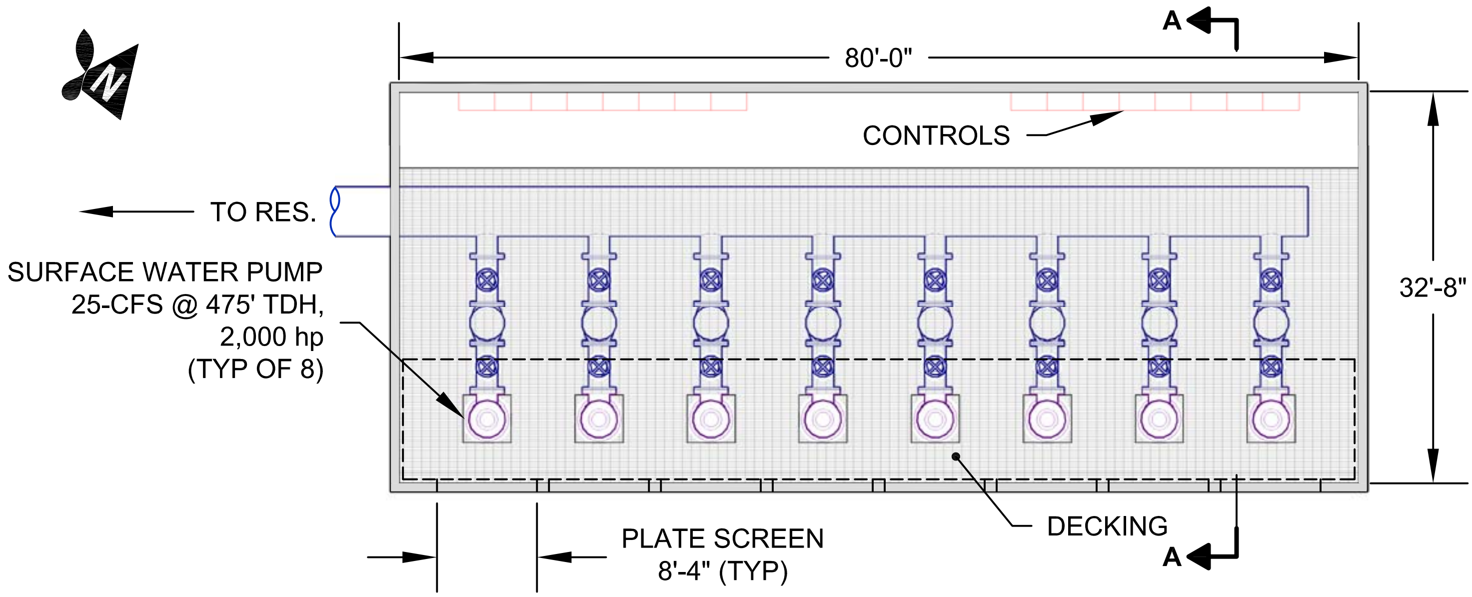
SOURCE: Basemap Contours (5-foot interval) from USGS 10-meter Digital Elevation Model (DEM)

HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet

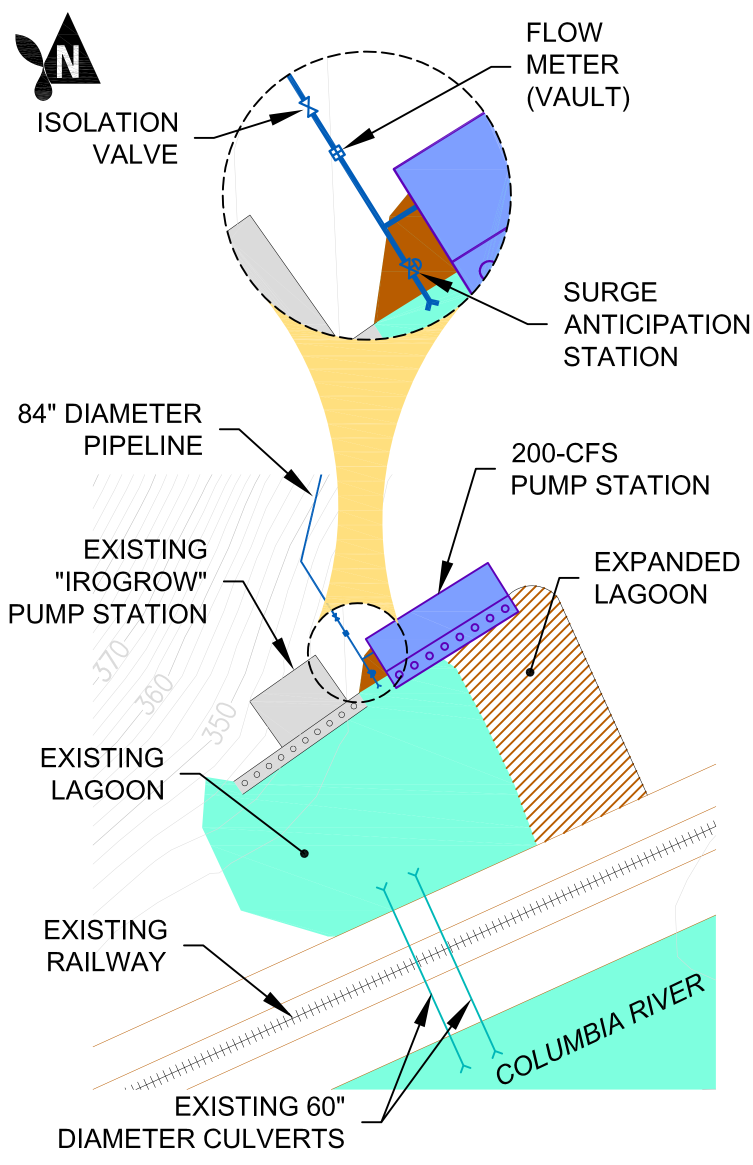
VERTICAL DATUM: NGVD 29

ANCHOR QEA

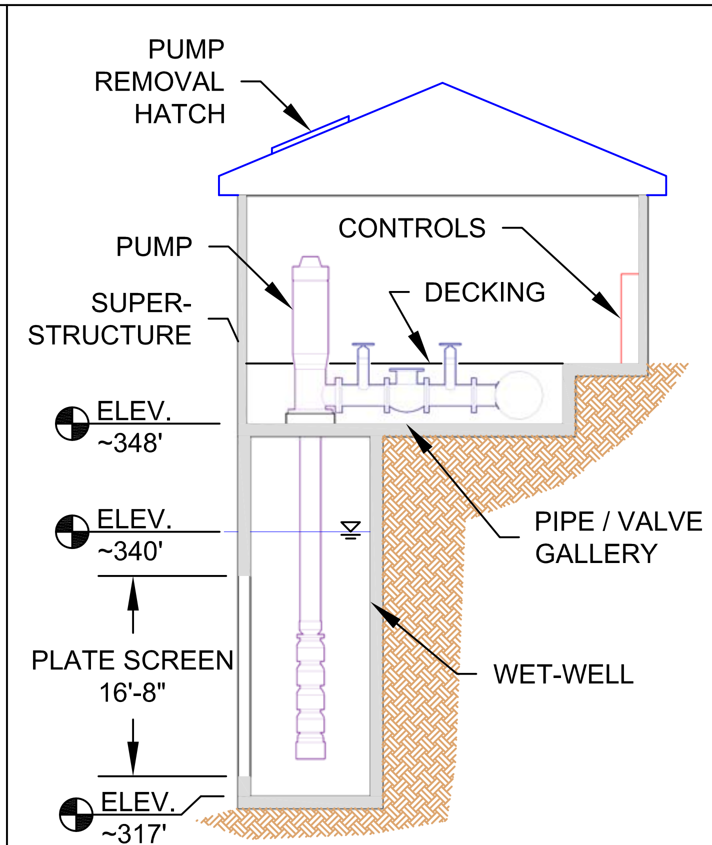
Figure 4-4
Spillway and Outlet Works Conceptual Plan
Phase II Report
Horse Heaven Water Storage Appraisal Assessment



PUMP STATION PLAN
(NOT TO SCALE)



SITE PLAN
(NOT TO SCALE)



A
SECTION
(NOT TO SCALE)

Pump Station

Conceptual Plan and Section

Horse Heaven Water Storage Appraisal Assessment

Refined Engineering and Cost Estimate

WRIA 31, Washington

Aspect CONSULTING	Dec-2012	BY: JRB/JLP	FIGURE NO.
	PROJECT NO. 090045	REV BY: -	4-5

CAD Path: Q:\WRIA\030009 WRIA 31\Switzler Reservoir\Figure 4-5 - Pump Station.dwg Figure Y || Coordinate System: NAD 1983 State Plane Washington North FIPS 4601 Feet || Date Saved: Dec 19, 2012 9:01am || User: rbrownlee

ATTACHMENT A

Project Economics

Aspect
CONSULTING

MEMORANDUM

Project No.: 090045-009-01

December 21, 2012

To: Dave McClure, Klickitat County
Adam Fyall, Benton County
Bruce Beauchene, City of Kennewick

cc: WRIA 31 Planning and Advisory Committee

From: **J. Ryan Brownlee, PE**
Senior Water Resources Engineer

Daniel R. Haller, PE
Associate Water Resources Engineer

Timothy J. Flynn, LHG, CGWP
Principal Hydrogeologist

Re: **Initial Benefit – Cost Assessment for Water Allocation Options, Switzler Reservoir, Horse Heaven Water Storage Appraisal Assessment, WRIA 31 Funded by Ecology Grant No. G1100215**

Introduction

This memorandum presents an initial evaluation of estimated costs and economic benefits under a range of potential scenarios for allocating a new water supply from the proposed Switzler Reservoir, and is presented for review and discussion with the WRIA 31 Planning and Advisory Committee (Advisory Committee). Based on Advisory Committee input, a refined water allocation scheme will be included as part of the Phase 2 Report for the appraisal assessment, taking advantage of refined project cost estimates that are currently in preparation.

This initial evaluation included limited coordination with economists from Washington State Department of Ecology (Ecology) and Washington State University (WSU), and application of industry-standard tools for estimating economic benefits associated with large-scale infrastructure projects. However, it is not intended as a detailed economics evaluation for the Switzler Reservoir water storage project (Project). It is intended to provide a starting point for discussion regarding how best to allocate the potential new water supply, and a first-cut fatal flaw analysis of Project economics consistent with the other technical analyses of the Phase 1 appraisal assessment. More detailed economic evaluation will be necessary should the Project proceed beyond this appraisal phase.

This assessment is part of Task 1.4 under the WRIA 31 Horse Heaven water storage appraisal assessment funded by Washington State Department of Ecology's (Ecology) Office of the Columbia River (OCR).

Summary of Findings

The proposed Switzler Reservoir storage project (Project) involves the creation of a new 44,000 acre-foot surface water impoundment in Switzler Canyon approximately 1-mile upstream of the Columbia River. The proposed new infrastructure includes an earthen dam approximately 325 feet tall with a crest length of approximately 2,000 feet. The construction also includes pumping, conveyance, and environmental mitigation improvements.

Project costs are currently estimated at approximately $281 million (capital) with additional ongoing (annual) operations and maintenance (O&M) costs estimated at $4.5 million (Aspect and Anchor QEA, 2012). Considering both capital and O&M on a per-year amortized basis, annual project costs are estimated at approximately $17.5 million ($427 per acre-foot, per year).
It is believed that this cost ($427 per acre-foot, per year) exceeds what the market may bear for pricing of water in the form of reimbursement through local recipients. Therefore, due to the scope and scale of this Project; grant funding from regional, state, and possibly federal sources will be required to augment local match funding[1].

A process which estimates the Project's resulting economic benefits places initial bounds on the magnitude of public funding which could be reasonably justified. The difference between the total Project cost and magnitude of public funding provides a 'balance' that represents the estimated cost (price) to be borne by prospective users of the stored water. Should that resulting balance equate to a value sufficiently low such that the market could bear, then the total cost is not a fatal flaw for Project development.

This memorandum lays out a preliminary process using two different economic tools (methodologies) to estimate Project benefits across various water allocation scenarios that may be preferred by the WRIA 31 Planning and Advisory Committee. These tools mimic those used by public water resources agencies to make decisions about Project economic viability. The results indicate that there are economic benefits that sufficiently approach (or exceed) current estimated Project cost levels. In other words, there are several likely scenarios that could be justifiably funded with a mix of public and private funding.

Based on this appraisal-level evaluation, Project economics are not identified as a fatal flaw. However, more detailed economic evaluation will be necessary should the Project proceed beyond this appraisal phase.

Summary of Economic Evaluation Methodologies

Although the new reservoir would have a maximum storage capacity of 44,000 acre-feet, the project would create an estimated 41,000 acre-feet of new mitigated supply[2]. New mitigation water could be used to appropriate new water rights for multi-purpose uses. The project involves putting water into storage, and establishing mitigated water rights for use of the stored water (indirectly). Distribution and use of most of the stored water (i.e., exercising the mitigation water rights) will likely be directly from the Columbia River rather than directly from the Switzler Reservoir. The stored water provides a new seasonal water supply that could:

[1] For example, rate or connection charges from municipal beneficiaries, assessments from irrigators, and drought leases by interruptible water users.
[2] 41,000 acre feet would be supplied with over 90% reliability based upon Columbia River water availability. In some years, new water supply would be curtailed to approximately 31,000 acre-feet (75%). This would occur on an approximate frequency of 1 in 10 years.

- Mitigate for interruptible water rights during drought years (sustaining current agriculture, and providing mitigation water for exercise of the Quad Cities municipal water right).
- Mitigate for new water rights (expanding the agricultural economy or benefiting new municipal growth).
- Improve instream flows and habitat in Switzler Canyon downstream of the reservoir and in the mainstem Columbia River.

During the irrigation season, water stored in the Switzler Reservoir would be released back to the Columbia River or directly pumped from the reservoir by nearby irrigators using their systems. Water released from the Switzler Reservoir back to the Columbia River could mitigate for diversions from McNary Pool, John Day Pool, or any downstream reach of the mainstem.

Due to the scope and scale of the proposed Project, it is anticipated that grant funding from regional, state, and possibly federal sources will be required to augment local match funding. The level of public funding is directly related to the public economic benefit derived. For projects involving substantial public funding, the standard practice for justifying such funding is through the implementation of a benefit-cost assessment (BCA). To justify complete grant funding, the BCA must yield a result in which project benefits exceed costs borne by the public (B/C ratio greater than 1.0 [at a minimum]). Public agencies such as Ecology, Bureau of Reclamation, and US Army Corps of Engineers use various input-output models to perform BCA on projects which they consider for funding.

A thorough BCA which evaluates multiple economic market sectors in detail is beyond the scope of this appraisal assessment. However, to provide meaningful information for decision making at this stage, a high-level assessment of potential public benefits has been performed using BCA-type methodologies. Estimation of the Project's economic benefits places initial bounds on the magnitude of public funding which could be reasonably justified. Having an estimate of public funding for the Project, combined with estimated total costs of the Project, provides, by subtraction, a first-cut estimate of the cost (price) to be borne by prospective users of the stored water ($ per acre-foot). If that prospective cost is what the market will bear (e.g., what cities charge for developing new water supply, what irrigators pay to bring water to their property, and what interruptibles will lease water for), then the total cost is not a fatal flaw for project development. For this initial assessment, two complimentary tools (methodologies) have been employed to estimate benefits:

- **The first methodology** is similar to an economic development (NED/RED) input-output economic model employed by federal agencies such as Bureau of Reclamation and the U.S. Army Corps of Engineers to quantify economic benefits of project proposals on both national and regional scales (Method 1). Using this method, various scenarios of water allocation among a variety of project beneficiaries (agricultural, municipal, and environmental [instream benefit]) were considered and economic values for each beneficiary group were estimated.
- **The second methodology** estimates the economic effects related to property values and jobs created at the State level as a result of the Project (Method 2). This method is primarily used by Washington State Department of Ecology's (Ecology) Office of the Columbia River (OCR) in evaluating economic viability of prospective State-funded projects. Ecology's OCR utilizes the Washington State Office of Financial Management (OFM)

2002 Input-Output model which has been tailored to account various sectors in the Washington State economy specifically.

In employing each method, economist Mike Brady of Washington State University (Method 1) and economist Kasia Patora of Washington State Department of Ecology (Method 2) were consulted.

Both methodologies seek to compare economic benefit to project costs in terms of "present value", that is, the present-day value of the complete stream of benefits and costs throughout the project life span. For planning purposes on this Project, we assumed a Project life of 100 years and a discount rate of 4.0%, which is the current discount rate assumed for federal water resources projects for fiscal year 2012[3].

Final water pricing will be driven by two elements: 1) the balance of costs which are in excess of non-reimbursable public grant funding sources; and 2) market forces. For example, should available grant funding cover only 75% of the Project costs, the remaining 25% of the costs would be recovered through pricing of mitigated water rights (subject to willingness/ability to pay).

Ultimately, a water allocation that maximizes economic benefit while meeting Project objectives, including environmental benefit, is optimal.

Summary of Potential Economic Effects

This section briefly summarizes the results of the BCA. Subsequent sections provide additional detail regarding the estimated Project costs and benefits.

Estimated Project Cost

Project costs include both capital (planning, design, and construction) and ongoing operations and maintenance (O&M) costs total approximately $304 million (present value) based upon current estimates.

Estimated Project Benefits

Method 1, Economic Development, Input-Output Methodology

Six scenarios were developed to illustrate potential economic development impacts related to water allocation (see Table 1). Each water allocation scenario represents a different mix of water appropriation between the various beneficiary groups considered (agricultural, municipal, or instream). Scenarios 1, 2 and 3 represent 'extremes' which allocate the full supply to individual beneficiary groups. These scenarios are not intended to represent the most likely outcomes, but rather illustrate the magnitude of variation between the potential beneficiaries under various extremes. In contrast, Scenarios 4, 5 and 6 seek to illustrate more balanced allocations. That is, scenarios which provide water supply to multi-purpose beneficiaries. For example, Scenario 4 divides the 41,000 acre-foot supply evenly between three groups; new agriculture, municipal and instream. Scenario 6 is similar to Scenario 4, with the exception that drought supply related to interruptible agriculture is included, and at an equal proportion to new agriculture, municipal, and instream. Scenario 5 illustrates the economic impact of allocating the full supply to agriculture (50% new/50% interruptible).

Using economic development input-output type methodology, the estimated present value of overall project benefits for six assumed water allocation scenarios range from approximately $19

---

[3] https://federalregister.gov/a/2011-30641

million to $1.2 billion. The range is broad, representing “book end” conditions across a range of choices that the Advisory Committee may endorse and for which funding may be available. The scenarios selected as part of this study range from those focusing on one beneficiary group (scenarios 1, 2, 3 and 5) to the exclusion of others (e.g., agriculture over municipal or vice versa), to more balanced scenarios where the storage benefits are allocated to multiple beneficiaries. For example, within the balanced scenarios, the total present value of Project benefits range from approximately $353 million to $439 million compared to a cost of $304 million. Using this methodology, it appears that the Project’s economic benefits could ultimately approach or exceed Project costs (B/C ratio greater than 1.0); therefore, Project economics do not appear to represent a fatal flaw at this time. A tabulation of economic benefits relative to Project costs for several water allocation scenarios using economic development input-output type methodology are presented in Table 1.

Table 1 – Benefit Cost Analysis, Method 1

Scenario	Benefit Allocation (acre-feet)				Local Match (per acre-foot, per-year)	Total Benefit less Total Cost (PV)	B/C Ratio	Total Project Cost, Including O&M (PV)	Total Project Benefit (PV)
	Agriculture	Drought	Municipal	Instream					
1	41,000	0	0	0	*	$927,271,806	4.0	$304,423,118	$1,231,694,924
2	0	0	41,000	0	$269	-$237,082,369	0.2	$304,423,118	$67,340,749
3	0	0	0	41,000	$324	-$285,086,840	0.1	$304,423,118	$19,336,277
4	13,667	0	13,667	13,667	*	$135,034,746	1.4	$304,423,118	$439,457,864
5	20,500	20,500	0	0	*	$357,504,437	2.2	$304,423,118	$661,927,555
6	10,250	10,250	10,250	10,250	*	$48,209,916	1.2	$304,423,118	$352,633,034

PV: Present value.
*See Local Match section (below).

Local Match

Local match represents the potential funding shortfall balance that would be borne by prospective users of the stored water (per acre-foot[4]). For the purposes of this study, this amount is calculated by subtracting total Project cost from total Project benefit and distributing the balance evenly among the water supply[5]. The amount of local match varies by water allocation scenario, ranging from $269 to $324 per acre-foot (amortized). In some scenarios (Scenarios 1 and 5), total Project benefit significantly exceeds total Project cost, which implies that little or no private contribution in the form of local match may be necessary. However, as a practical matter, few public funding sources exist to cover the on-going pumping and operation O&M portion of the total project costs. By contrast, more options are available for capital project construction. Current estimates identify

[4] Local match in terms of $ per acre-foot reported in Table 1 represents amortized (yearly) amount based upon assuming a loan term of 50 years at 4.0% interest.
[5] It is likely the case that the various beneficiary groups have different thresholds for market pricing. For example, willingness of private parties to pay for water for agricultural purposes may be higher than that of private parties for instream benefits (per acre-foot).

the power and O&M costs for Switzler Reservoir as $109 per acre-foot. Unless a perpetual funding source is identified that can subsidize this cost, this may represent a lower bound on local match.

Method 2, Ecology OFM, Input-Output Methodology

Improvements to property values and jobs in Benton and Klickitat Counties were estimated for various water allocation scenarios (agricultural and domestic) using Method 2. Because this methodology relies on inputs related to agricultural and municipal supply only, three scenarios were developed which loosely correspond to Scenarios 1, 2, and 5 of Method 1.

Improvements to property values for various scenarios range widely from approximately $63 million on the low end to nearly $14 billion on the high end. Potential job benefits associated with scenarios range from approximately 900 to 85,000 new jobs created (excluding temporary construction related jobs)[6]. A tabulation of economic benefits relative to project costs for several water allocation scenarios using property value and jobs methodology are presented in Table 2.

Table 2 – Benefit Analysis, Method 2

Scenario	Benefit Allocation		Total Project Benefit - Improved Land Value (PV)	Total Project Benefit - Jobs Added
	Agriculture	Municipal		
1	41,000	0	$63,357,368	894
2	0	41,000	$13,540,715,794	85,235
5	20,500	20,500	$6,802,038,831	43,065

Estimated Project Costs

Project costs include both capital costs and ongoing O&M costs. Current capital construction cost is estimated at approximately $281 million, which was assumed to be repaid over a period of 50 years at a rate of 4.0%. For the purposes of this analysis, we assume that construction would begin in 2017 and last 5 years, with the project becoming available for use in 2022. Ongoing O&M costs are estimated at $3.5 million per year beginning upon construction completion in 2022. O&M costs will continue through the life of the Project, which is currently estimated at 100 years from construction completion (i.e., until 2116).

Figure 1 illustrates both the estimated yearly project costs including capital plus O&M (red line), as well as the present value of the annual costs using a discount rate of 4.0% per year (blue line). The drop in Project cost at 2067 indicates full repayment of the 50-year-amortized capital costs. The

[6] In comparison, Ecology OFM results for Sullivan Lake which is an Office of Columbia River (OCR) funded project, resulted in an estimated economic benefit if $1.4 billion in additional tax base, 1,483 short run jobs and 1,753 long run jobs from the creation of approximately 9,400 acre-feet of new supply (50% municipal/industrial [M&I] allocation / 50% other [agricultural, stockwater, etc.]) http://www.ecy.wa.gov/programs/wr/cwp/sullivan.html. Similarly, Ecology OFM results for the Lake Roosevelt drawdown (OCR project) result in an estimated economic benefit of $3-billion and 35,000 new jobs from the creation of approximately 55,000 acre-feet of new supply (30,000 acre-feet for Odessa [agricultural] / 25,000 acre-feet for M&I) http://www.ecy.wa.gov/programs/wr/cwp/cr_lkroos.html.

sum of present value of annual costs (area under curve) represents the total present value of capital costs associated with the Project, and has been calculated at approximately $304 million.

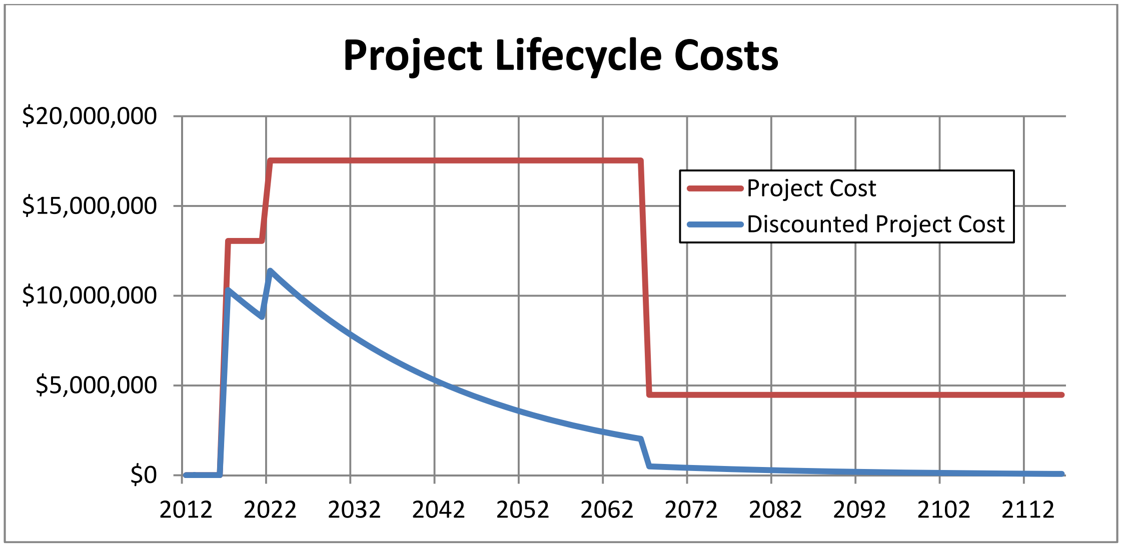


Figure 1 - Estimated Annual Project (Capital + O&M) Costs, 2012 to 2112

Un-quantified Project Costs

In addition to estimated project costs, un-quantified project costs exist which should be acknowledged and could be quantified as a result of further study.

Due to the potential increased water supply and subsequent increase in agricultural output, additional economic costs may exist related to the general decrease in the value of goods and services derived from the Horse Heaven area. That is, as supply increases, unit cost may drop. Quantification of these additional economic cost impacts are complex and outside of the scope of this Project and therefore have not been estimated at this stage.

Also, Project costs associated with conveying and making use of the water made available by the Project have not been accounted for as part of this study. That is, new water supply made available from this Project is simply 'mitigation' water (as opposed to direct water supply). Individual users will experience varying levels of additional costs associated with physically capturing and transmitting water to their intended place of use. For example, additional pumps and piping from the river to new farmlands will be needed, along with the on-farm irrigation infrastructure in order to put lands into production that cannot be served directly from the reservoir. These additional unquantified costs would directly impact end user willingness/ability to pay, which suggests the need for a higher B/C ratio than 1.0, such as those evaluated in Scenarios 1 and 5 (Table 1).

Finally, it is anticipated that economic effects exist related to impact to hydropower supply along the mainstem of the lower Columbia River as a result of this Project. We expect that most of the water stored in the Switzler Reservoir will be allocated to out-of-stream uses (much of which will be consumed). Consumption of water formerly available at lower Columbia River Dams (e.g., John Day, Bonneville) will result in lost power revenue. Quantification of this impact is beyond the scope of this study; however, it is assumed that this impact will be nominal, primarily because filling will likely occur when surplus water exists in the river. There may even be potential for power benefit by adding electric load opportunistically by coordinating refilling with times when excess power exists in the system.

Estimated Project Benefits

Two independent methods were used to estimate project benefits for the proposed storage Project. Each methodology is described below.

Method 1, Economic Development, Input-Output Methodology

In consultation with Washington State University, the first method used is to estimate Project benefits relies on an input-output-type process in which the economic values of goods and services across multiple project beneficiaries are determined. Where possible, economic benefits quantified under this methodology include effects classified as direct, indirect, and induced. Direct, indirect, and induced effects are characterized by the following:

- Direct effects are new expenditures that directly result from the project (e.g., sales of a crop);
- Indirect effects are secondary changes in the economy as are result of direct effects (e.g., fertilizer for a crop); and
- Induced effects represent the money that is re-spent in the economy as a result of increased spending from direct and indirect effects (e.g., food sales, gas, etc.).

Project beneficiaries considered include agricultural (both new and drought mitigation), municipal (domestic water supply), and instream (fish). Multiple water allocation scenarios consisting of different mixes of beneficiaries were considered to develop low/high "bookends" as well as more realistic (balanced) allocations.

Agricultural Benefits

Methodology

Agricultural benefits were quantified using methodology similar to IMPLAN® input-output model which is a tool used by economists such as Mike Brady of Washington State University to model regional impacts related to agricultural projects that affect the economy. This methodology relies on factors which are applied to farm-gate revenue to determine direct, indirect, and induced economic impacts. Based on discussion with Mike Brady, the factors associated with direct, indirect, and induced impacts were selected as 1.0, 0.7, and 0.4, respectively, which simulate IMPLAN® output.

Direct economic impacts are defined as those which are directly related to the goods and services produced. In this case, farm gate revenues for various crops were considered direct impacts. Farm gate revenues were estimated by translating water supply quantity to new irrigated acreage using Washington Irrigation Guide methodology and considering a crop mix representative of the Horse Heaven region for various scenarios (USDA/NRCS, 1997). The assumed crop mix consisted of potatoes (30%), sweet corn –fresh market (11%), sweet corn – process market (11%), field corn (12%), grapes (26%), and apples (10%)[7]. Farm gate unit price revenue ($ / acre) were applied to

[7] USDA statistics indicate that in 2007, approximately 32,000 acres of potatoes, 22,500 acres of sweet corn, 12,600 acres of field corn, 23,300 acres of grapes and 10,000 acres of apples were grown in Benton County representing proportions of approximately 30%, 22%, 12%, 26%, and 10%, respectively. It is assumed that the sweet corn production was divided evenly between the fresh and process markets (11% each, of total).

new acreage based upon USDA/NASS 2011 Washington Annual Agricultural Bulletin data for the various crops selected (USDA/National Agricultural Statistics Service, 2011)[8].

Indirect and induced economic impacts were then calculated and incorporated into the total benefit using the assumed factors stated above. Indirect impacts include economic activities which are necessary to support the production of the goods and services considered as direct impacts (seed, fertilizer, equipment, etc.). Induced impacts represent yet a further layer of support and include economic impacts such as need for additional goods and services (food sales, fuel, etc.).

Agricultural Benefit – New Irrigated Acreage

Annual agricultural economic benefits for new irrigated acreage were calculated using an assumption that a gradual build out would occur over time with approximately 25% of new acreage brought online by 2027, 50% by 2037, and 100% by 2047. Present value of annual agricultural economic benefits for various irrigation water allocation levels were calculated, and are displayed on Figure 2. Annual present values of agricultural benefits (direct, indirect, and induced) were totaled for each scenario to determine total present value of agricultural benefits. Total present value of agricultural benefits over the assumed 100-year life of the project for various agricultural water allocation levels are shown in Table 3.

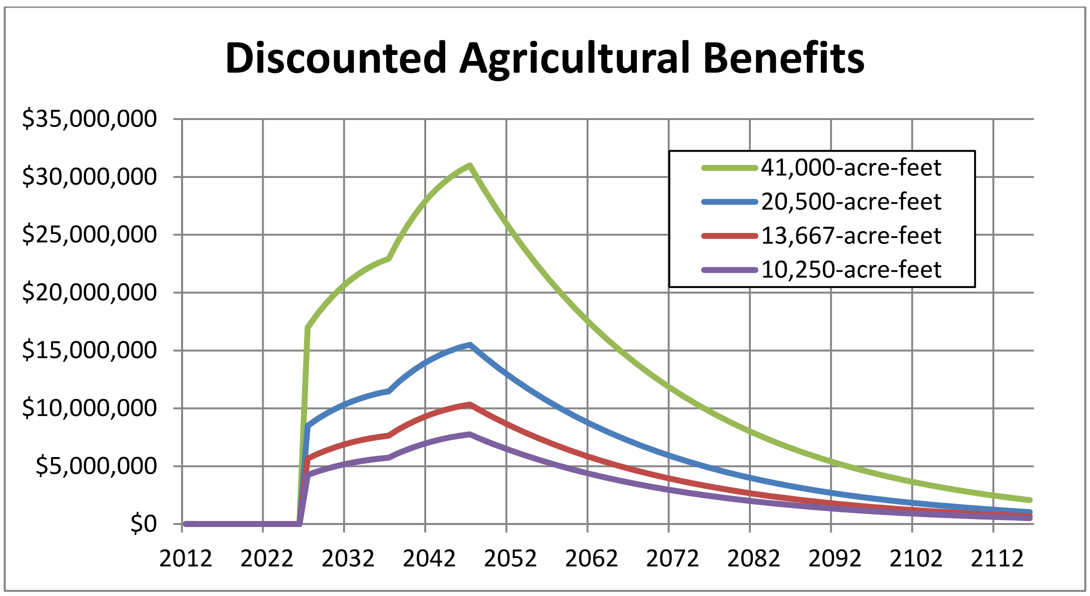


Figure 2 – Estimated Annual Present Value of Agricultural Economic Benefits (New Irrigated Acreage for Various Allocations of New Irrigation Water Supply)

[8] The extent to which new irrigated agricultural acreage will displace existing dry-land farming practices (such as dry-land wheat) has not been quantified as part of this study. This effect would be reflected by a reduced net benefit associated with new irrigated acreage (where applicable).

Table 3 – Estimated Total Present Value of Agricultural Economic Benefits over Assumed 100-Year Project Life (New Irrigated Acreage for Various Allocations of New Irrigation Water Supply)

Agricultural Benefit (New)	
Quantity (Acre-Feet)	**Present Value**
41,000	$1,231,694,924
20,500	$615,847,462
13,667	$410,564,975
10,250	$307,923,731

Agricultural Benefit – Drought Mitigation

Interruptible water rights within the Horse Heaven area exist and are subject to curtailment during drought years. A proportion of the stored water could be dedicated to this group for use as drought mitigation supply. For the purpose of this assessment, a drought frequency of 1 in 20 years was assumed[9]. In other words, it is anticipated that five instances of drought may occur over the assumed 100-year project life cycle. In order to estimate an agricultural drought mitigation economic benefit, the five instances of drought were assumed to occur at 20-year intervals, and present values of agricultural benefit of each of those instances were calculated (benefit = value of crops not lost to drought). Economic benefit of each drought year for various water allocation scenarios was computed using similar water budget methodology as the new agriculture exercise described above (Washington Irrigation Guide methodology, representative crop mix, etc.).

It is understood that additional benefit related to drought mitigation may exist due to the likely conversion of low-value crops to higher-value crops as a result of a more reliable source of water becoming available. These benefits have not been calculated due to the limited nature of this assessment.

The total present value of economic benefit for the five instances of drought over the assumed 100-year life of the project under multiple water allocation scenarios are shown in Table 4.

Table 4 – Estimated Total Present Value of Agricultural Economic Benefits over Assumed 100-Year Project Life (for Various Allocations of Drought Mitigation Water Supply)

Agricultural Benefit (Interruptible)	
Quantity (Acre-Feet)	**Present Value**
20,500	$46,080,094
10,250	$23,040,047

[9] For example, since the Columbia River instream flow was adopted in 1980, interruptible water users have only been curtailed once in 2001, which would represent a 1:32 year event (from 1980 to 2012). However, had the rule been adopted in 1977 (also a severe drought year), then interruptibles would have been curtailed twice in the period (e.g., 2 in 35 years or about 1:17 year event). Therefore, Aspect selected 1:20 as an estimate in this memo.

Municipal Benefits
Municipal economic benefits are associated with new water supply for use by municipal water purveyors including the Quad Cities (project would make available new mitigated water rights within McNary Pool). The estimated benefits associated with municipal are based upon a cost-avoided approach. That is, provided that a new supply of domestic water is made available, cost of purchasing water at wholesale municipal prices from neighboring purveyors would be avoided – resulting in a net benefit. Using this approach, annual municipal economic benefits (cost-avoided) were estimated by applying a $235 per-acre foot per year wholesale water price to municipal water supply volumes (Reclamation, 2006).

Similar to the agricultural benefits methodology, it is assumed that municipal water supply benefit would be realized gradually with 25% brought online by 2027, 50% by 2047, and 100% by 2067. Present value of annual municipal economic benefits for various municipal water allocation levels were then calculated and are shown on Figure 3. Annual present values of municipal benefits were totaled for the assumed 100-year project life to determine total present value of municipal benefits. Total present value of municipal benefits for various agricultural water allocation levels are shown in Table 5.

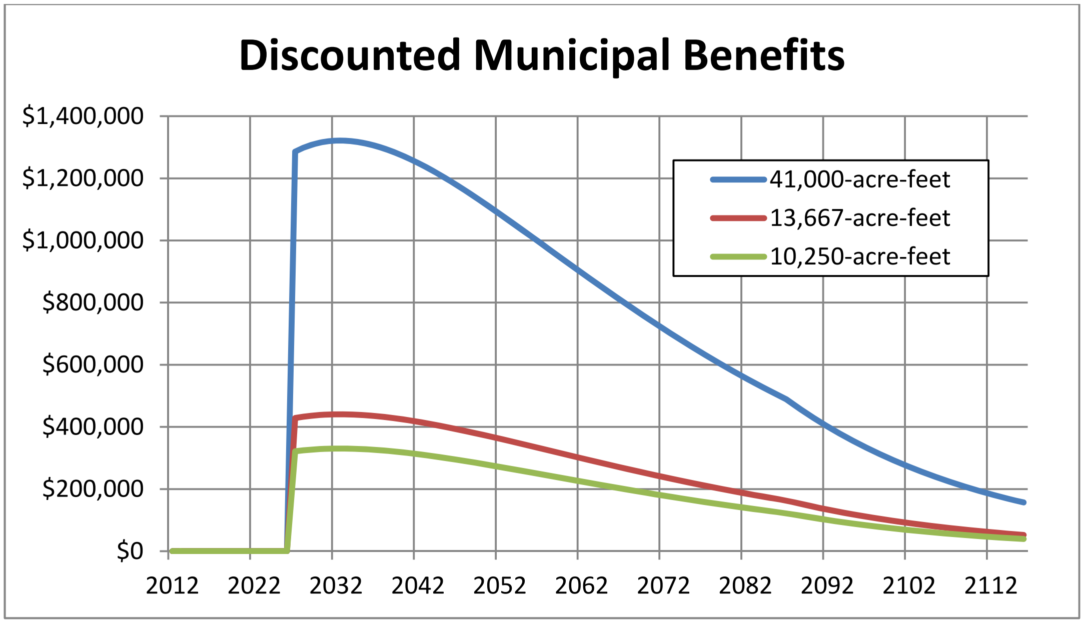


Figure 3 – Estimated Annual Present Value of Municipal Economic Benefits for Various Allocations of New Municipal Water Supply

Table 5 – Estimated Total Present Value of Municipal Economic Benefits over Assumed 100-Year Project Life (for Various Allocations of New Municipal Water Supply)

Municipal Benefit	
Quantity (Acre-Feet)	**Present Value**
41,000	$67,340,749
13,667	$22,447,464
10,250	$16,835,187

Instream Benefits

Methodology

Instream benefits consist of those which directly benefit aquatic habitat and fish, namely anadromous salmonids. Quantification of instream benefits is complex; therefore, for the purposes of this initial analysis, a range of benefits (low end and high end) were considered based upon general studies developed by others as well as analogous water supply projects with instream benefits.

Low-End Fish Benefits

For the purpose of this study, low-end fish benefits are defined as the more economically conservative limit of the range, and include those benefits to instream flows in the lower Columbia River only. The limited available literature related to water quantity benefit to fish suggests that value is on the order of $4 per acre-foot (Olsen and White, 2003).

It is assumed that instream benefits would be realized immediately upon project completion. Annual present values of low-end instream benefit were estimated for various instream water allocation levels and are illustrated on Figure 4. Annual present values of instream benefits were totaled for each scenario to determine the low end of total present value over the assumed 100-year life of the Project, as shown in Table 6.

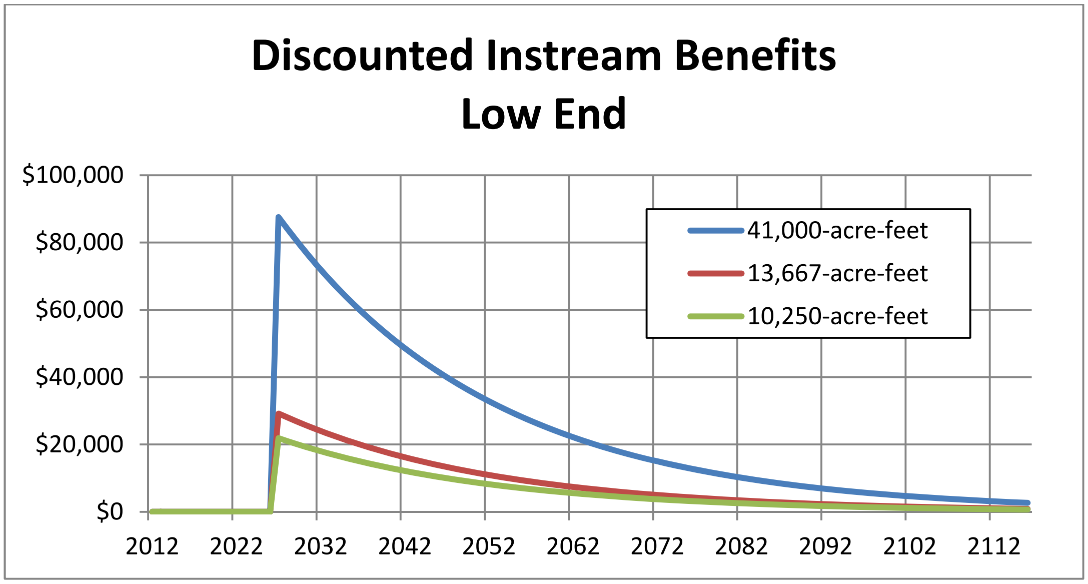


Figure 4 – Estimated Annual Present Value of Instream Economic Benefits (Low End) for Various Allocations of New Instream Water Supply

Table 6 – Estimated Total Present Value of Instream Economic Benefits (Low End) over Assumed 100-Year Project Life (for Various Allocations of New Instream Water Supply)

Fish Benefit (Low)	
Quantity (Acre-Feet)	Present Value
41,000	$2,209,860
13,667	$736,620
10,250	$552,465

High-End Fish Benefits

For the purpose of this study, high-end fish benefits are defined as the more exhaustive limit of the range and include those benefits related to improved stream flows directly within Switzler Canyon (itself) downstream of the dam plus benefits to Columbia downstream. Additional high-end benefit may exist related to high-flow and/or temperature refuges that might be created within Switzler Canyon as a result of environmental mitigation efforts.

Recent project examples indicate that a high-end market value for instream fish benefit approached $870 per acre-foot (capital). Such is the case with the Barker Ranch project recently funded by Ecology's OCR[10]. The benefits may also be higher for this project due to discrete habitat benefits within the downstream channel in Switzler Creek. Applying an assumed discount rate of 4% over a 100-year Project term equates to an instream benefit of approximately $35 per acre-foot per year.

[10] http://www.ecy.wa.gov/programs/wr/cwp/barker.html.

Applying this assumption, annual present values of high-end economic fish benefit were estimated for various water allocation levels and are illustrated in Figure 5. Annual present values of instream benefits were totaled to determine the high-end total present value of instream benefits. Total present value of instream benefits over the assumed 100-year life of the Project for various water allocation levels are shown in Table 7.

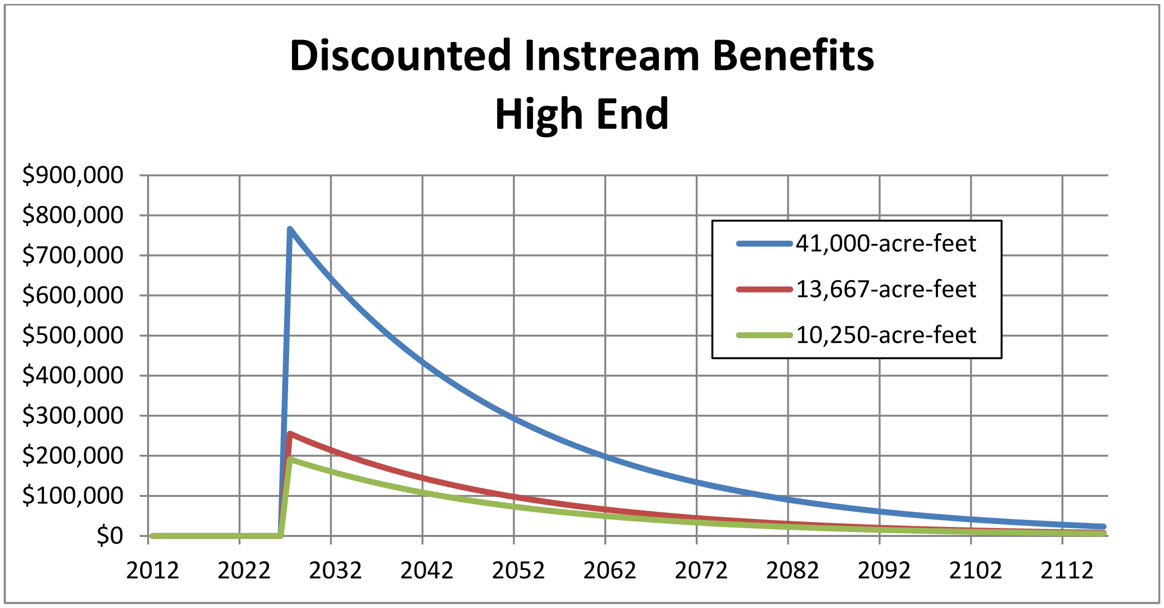


Figure 5 – Annual Present Value of Instream Economic Benefits (High End) or Various Allocations of New Instream Water Supply

Table 7 – Total Present Value of Instream Economic Benefits (High End) over Assumed 100-Year Project Life (for Various Allocations of New Instream Water Supply)

Fish Benefit (High)	
Quantity (Acre-Feet)	Present Value
41,000	$19,336,277
13,667	$6,445,426
10,250	$4,834,069

Method 2 – Ecology OFM, Input-Output Model

Methodology

As part of this study, the OFM model was used by Ecology to generate ‘scalable’ economic values related to new homes, new irrigated acreage, and jobs created. Using the OFM model, 1,000 new homes and 1,000 acres of new irrigated land (in both Benton and Klickitat Counties) were used to determine corresponding improved land value and new jobs created (increased tax base). This methodology is commonly employed by Ecology’s OCR in evaluating economic effects related to developing various water supply projects.

Potential new water supply for various irrigation water allocation scenarios was translated to new irrigated acreage using Washington Irrigation Guide methodology and considering the same representative crop mix as applied in Method 1(USDA/NRCS, 1997). Farm gate unit revenues ($ / acre) were applied to new acreage based upon USDA/NASS 2011 Washington Annual Agricultural Bulletin data for the various crops selected (USDA/National Agricultural Statistics Service, 2011).

The number of new homes corresponding to water supply allocation level was estimated by applying an average daily demand of 555 gallons per day per home based upon 2009 City of West Richland Comprehensive Water System Plan data (J-U-B Engineers, Inc., 2009).

Scaled data provided by Ecology related to improved land value and jobs created are summarized in Tables 8 and 9[11].

Table 8 – Estimated Improved Land Value, Benton and Klickitat Counties

	Benton County	Klickitat County
Improved Land Value - Domestic (Per Home)	$165,798	$244,864
Improved Land Value - Agriculture (Per Acre)	$540	$8,458

Table 9 – Estimated Jobs Created, Benton and Klickitat Counties

	Benton County	Klickitat County
Jobs From Domestic (Per Home)	1.04	1.54
Jobs From Agriculture (Per Acre)	0.01	0.12

An even distribution of water supply (50% Benton County/50% Klickitat County) was applied to the various scenarios to determine total improved land value (agricultural and domestic) and jobs which has been tabulated in Table 2[12].

References

Aspect Consulting, LLC (Aspect) and Anchor QEA, 2010, Water Storage Pre-Feasibility Assessment Report, Horse Heaven Area, WRIA 31, October 2010.

J-U-B Engineers, Inc., 2009, Water System Plan Update, City of West Richland, October 2009.

Olsen, D. and White, T., 2003, Estimating the Value of Water from Key Resource Sectors from the Mainstem Columbia River, Pacific Northwest Project Technical Memorandum, October 2003.

[11] Variation in improved agricultural land value between Benton and Klickitat Counties is dramatic due to the existing variation in median farm property value between the two counties. That is, median farm values in Benton County are currently relatively high compared to Klickitat County, therefore increase in property values will be less substantial on a per-farm basis in Benton County.

[12] It is likely the case that an unbalanced water supply between the two counties would result depending upon beneficiary group demand at the time water becomes appropriated, etc. For example, a disproportionate amount of new water supply might go to new municipal water rights appropriations in Benton County (as opposed to Klickitat), which would drive the overall improved domestic land values reported in Table 2 down.

Reclamation, 2006, 2006 M&I Water Rate Survey Data, U.S. Bureau of Reclamation, Office of Program and Policy Services, Contract Services Office, Denver Co.

USDA/National Agricultural Statistics Service, 2011, 2011 Washington Annual Agricultural Bulletin, 2011.

USDA/NRCS, 1997, United States Department of Agriculture/Natural Resources Conservation Service, Part 652 Irrigation Guide, National Engineering Handbook, September 1997.

Limitations

Work for this project was performed and this memorandum prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

All reports prepared by Aspect Consulting are intended solely for the Client and apply only to the services described in the Agreement with Client. Any use or reuse by Client for purposes outside of the scope of Client's Agreement is at the sole risk of Client and without liability to Aspect Consulting. Aspect Consulting shall not be liable for any third parties' use of the deliverables provided by Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

W:\090045 WRIA 31 Phase 4\Deliverables\Phase 2 Report\Appendices\Apx A Preliminary Benefit-Cost Analysis\HHH Project Economics Memo Draft 8-20-12_rev2012 12 19.docx

ATTACHMENT B

Supporting Calculations for Opinion of Probably Costs

Appendix B

Table B-1 - Opinion of Probable Project Cost

Phase 2 Report: Refined Engineering and Cost Estiamte for Switzler Resvoir, Horse Heaven Water Storage Assessment, WRIA 31, Washington

			Alternative-1 Zoned Rockfill		Alternative-2 Decked Rockfill	
	Unit	Unit Cost	Quantity	Extended Cost	Quantity	Extended Cost
General				**$20,470,000**		**$18,590,000**
Mobilization	LS	VARIES	1	$19,910,000	1	$18,030,000
Construction Staging, Equipment Maintenance and Temporary Office	LS	$560,000	1	$560,000	1	$560,000
Sitework				**$20,519,000**		**$20,519,000**
Temporary Access Roadways	LS	$6,000,000	1	$6,000,000	1	$6,000,000
Clearing and Grubbing	AC	$4,000	230	$919,000	230	$919,000
Stripping Topsoil, Including Haul and Disposal	CY	$10	185,000	$1,850,000	185,000	$1,850,000
Diversion and Care of Water	LS	$2,000,000	1	$2,000,000	1	$2,000,000
TESC	AC	$5,000	500	$2,500,000	500	$2,500,000
Relocation of Existing Utilities (Major Irrigation Lateral)	LS	$2,000,000	1	$2,000,000	1	$2,000,000
Relocation of Existing Farm to Market Roadway	LS	$3,800,000	1	$3,800,000	1	$3,800,000
Revegetation / Property Restoration	AC	$3,500	100	$350,000	100	$350,000
Permanent Access Roadway	LS	$700,000	1	$700,000	1	$700,000
Site Fencing and Security	LS	$400,000	1	$400,000	1	$400,000
Embankment Dam				**$130,391,000**		**$113,473,000**
Foundation Excavation, Soil Material, to Stockpile	CY	$4	203,000	$812,000	0	$0
Foundation Excavation, Soil Material, Export Offsite	CY	$10	0	$0	203,000	$2,030,000
Foundation Excavation, Rock Material, to Stockpile	CY	$22	327,000	$7,194,000	327,000	$7,194,000
Foundation Excavation, Cutoff Trench	CY	$22	14,000	$308,000	4,500	$99,000
Foundation Grouting	SF	$10	400,000	$4,000,000	200,000	$2,000,000
Embankment Construction, Core Material	CY	$45	1,000,000	$45,000,000	0	$0
Embankment Construction, Rockfill	CY	$23	2,890,000	$66,123,000	3,955,000	$90,490,000
Embankment Construction, Filter Zone	CY	$26	260,000	$6,696,000	0	$0
Embankment Construction, Upstream Concrete Face Membrane	SY	$110	0	$0	58,000	$6,380,000
Embankment Construction, Cushion Zone for Concrete Face	CY	$26	0	$0	195,000	$5,022,000
Embankment Construction, Crest Surfacing	CY	$26	10,000	$258,000	10,000	$258,000
Operational and Appurtenances				**$11,552,000**		**$11,552,000**
Inlet/Outlet Works	LS	$2,213,000	1	$2,213,000	1	$2,213,000
Spillway / Stilling	LS	$4,256,000	1	$4,256,000	1	$4,256,000
Conveyance Pipeline	LF	$657	5,800	$3,811,000	5,800	$3,811,000
Outfall	LS	$1,272,000	1	$1,272,000	1	$1,272,000
Surface Water Pump Station				**$14,297,000**		**$14,297,000**
Site Preparation	LS	$100,000	1	$100,000	1	$100,000
Cofferdam / Dewatering	LS	$835,000	1	$835,000	1	$835,000
Structure Excavation	CY	$40	2,660	$106,000	2,660	$106,000
Dredging	CY	$50	7,000	$350,000	7,000	$350,000
Temporary Shoring	LS	$200,000	1	$200,000	1	$200,000
Pump-deck / Wetwell	LS	$400,000	1	$400,000	1	$400,000
Structure Backfill	CY	$45	1,900	$86,000	1,900	$86,000
Intake and Screening	LS	$2,000,000	1	$2,000,000	1	$2,000,000
Superstructure	LS	$480,000	1	$480,000	1	$480,000
Pumps	LS	$4,240,000	1	$4,240,000	1	$4,240,000
Piping/Mechnaical	LS	$1,000,000	1	$1,000,000	1	$1,000,000
Site Piping	LF	$600,000	1	$600,000	1	$600,000
Electrical	LS	$2,900,000	1	$2,900,000	1	$2,900,000
Controls	LS	$900,000	1	$900,000	1	$900,000
Site Access / Security	LS	$100,000	1	$100,000	1	$100,000
Environmental Mitigation				**$2,470,000**		**$2,470,000**
Downstream Channel Improvement	LS	$1,000,000	1	$1,000,000	1	$1,000,000
Wetlands Mitigation	LS	$1,150,000	1	$1,150,000	1	$1,150,000
Shrub Steppe Mitigation	LS	$320,000	1	$320,000	1	$320,000
Construction (Contract) Cost Subtotal				**$199,699,000**		**$180,901,000**
Construction Contingency (25%)			25.0%	$49,925,000	25.0%	$45,225,000
Construction (Contract) Cost Subtotal, Incl. Contingency				**$249,624,000**		**$226,126,000**
Washington State Sales Tax (7.7%)			7.7%	$19,221,000	7.7%	$17,412,000
Contract Cost Total				**$268,845,000**		**$243,538,000**
Land Acquisition	AC	450	1,000	$450,000	1,000	$450,000
Studies, Engineering, Permitting and Project Administration			15.0%	$40,327,000	15.0%	$36,531,000
Non-Contract Total				**$40,777,000**		**$36,981,000**
Project Cost Total				**$309,622,000**		**$280,519,000**

ATTACHMENT C

Site Photographs

Photograph 1 (9/2011)

Photograph 2 (9/2011)

Photograph 3 (9/2011)

Photograph 4 (9/2011)

Photograph 5 (9/2011)

Photograph 6 (9/2011)

Photograph 7 (9/2011)

Photograph 8 (9/2011)

Photograph 9 (9/2011)

Photograph 10 (11/20012)