PHASE 1 REPORT: HORSE HEAVEN WATER STORAGE APPRAISAL ASSESSMENT

WRIA 31

Prepared for: WRIA 31 Planning and Advisory Committee

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Aspect CONSULTING

DEPARTMENT OF ECOLOGY
State of Washington

Aspect
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Aspect Consulting, LLC

State of Washington
Hydrogeologist
272
Licensed Geologist
Steve J. Germiat

Timothy J. Flynn

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

Timothy J. Flynn, LHG, CGWP
Principal Hydrogeologist
tflynn@aspectconsulting.com

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Executive Summary

This report presents Phase 1 of the appraisal assessment for Alder Reservoir and Switzler Reservoir – the pair of in-channel surface reservoirs that are the major elements of the preferred storage alternative for the Horse Heaven area of Water Resource Inventory Area 31 (WRIA 31) identified in the *Water Storage Pre-Feasibility Assessment Report for the Horse Heaven Area, WRIA 31* (dated October 2010).

The 2010 pre-feasibility assessment identified no fatal flaws with the preferred alternative, but acknowledged that additional evaluation is warranted to identify potential fatal flaws prior to proceeding to more detailed engineering and design phases. Therefore, the appraisal assessment is organized into two phases. Phase 1 focuses primarily on more detailed evaluation of potential fatal flaws with the two proposed surface reservoirs. Phase 2 would proceed for one or both reservoirs if fatal flaws are not identified in Phase 1, and would involve refining the engineering assumptions for reservoir configuration and construction, and updating the current project cost estimates accordingly.

The Phase 1 refined fatal flaw assessment included field reconnaissance and other technical analyses to evaluate the potential reservoir permitting, construction, and operation issues associated with the technical disciplines of geologic stability, channel geomorphology, aquatic habitat, terrestrial habitat, cultural resources, and water quality. For each of the technical disciplines, this Phase 1 report presents our current understanding of conditions, anticipated issues for reservoir permitting and construction, and potential opportunities to mitigate the identified issues. This Phase 1 report also presents a preliminary assessment of the potential to integrate pumped storage into the project.

Based on the information generated from the collective technical studies of the Phase 1 appraisal assessment, the proposed Alder Reservoir is concluded to be fatally flawed as a result of landslide hazards. The canyon walls of the proposed Alder Reservoir contain numerous, mostly ancient, landslides. We conclude that repeated filling and emptying of the proposed Alder Reservoir – repeatedly saturating the numerous large landslide deposits - would create an unacceptable risk for re-activating the existing landslides and initiating new landslides. Such landslides could impair use of the reservoir, and, if new landslides are triggered, also create substantial damage and loss of land within properties surrounding the reservoir. Given the magnitude of the landslides within the proposed Alder Reservoir, we conclude there are no cost-effective means to mitigate that risk.

No fatal flaws are identified for the proposed Switzler Reservoir in terms of geologic stability, channel geomorphology, aquatic and terrestrial habitat, cultural resources, or predictive water quality. The Phase 1 studies identify numerous technical issues to address before Switzler Reservoir could be permitted and constructed, including geologic stability; however, at this appraisal stage of assessment, we judge that none of the issues constitute a fatal flaw.

We recommend that the proposed Switzler Reservoir proceed into Phase 2 of the appraisal assessment, in which refined engineering assumptions and cost estimates are developed and optimal uses of the stored water identified. The Phase 2 assessment will provide a better understanding of whether the proposed project economics (i.e., required price of new mitigated water rights made available by the project) constitute a fatal flaw.

1 Introduction

A priority recommendation of the WRIA 31 Watershed Management Plan is to develop water storage within WRIA 31 to address multipurpose water demands identified during the watershed planning process (WRIA 31 Planning Unit, 2008). The area of WRIA 31 with the greatest total water demand, and which also could achieve the greatest economic growth if new water supplies were made available, is the Wood-Glade Planning Area – the broad agricultural center of the watershed. The Wood-Glade Planning Area is more commonly known by the local community as the Horse Heaven, an approximately 1,200-square mile area bounded by the crest of the Horse Heaven Hills on the north and east, the shoreline of the Columbia River on the south, and the Rock Creek watershed on the west (Figure 1-1).

In 2009, Washington State Department of Ecology's (Ecology) Office of the Columbia River (OCR) funded a pre-feasibility assessment for the Horse Heaven area (grant number G0900153). The pre-feasibility assessment, reviewed by Ecology OCR and then finalized in October 2010 (Aspect Consulting and Anchor QEA, 2010), identified a range of water demands, develops a range of water storage alternatives to meet demands, and proposed a preferred storage alternative with initial fatal flaw analyses and planning-level cost estimates. The preferred storage alternative included a pair of in-channel reservoirs: Switzler Reservoir with an estimated 44,000 acre feet storage capacity; and Alder Reservoir with an estimated storage capacity ranging between 56,000 and 330,000 acre feet depending on whether potential impacts from the larger reservoir can be mitigated. The preferred storage alternative also included an assumed 10,000 acre-foot aquifer storage and recovery (ASR) capacity in the western basin where large-scale groundwater declines have occurred.

During discussions with local landowners at the start of this appraisal assessment, the owner of most of the land within the Alder Reservoir footprint indicated they would be interested in evaluating only the smaller, upper Alder Reservoir site; the larger 330,000 acre-foot option considered in the Pre-Feasibility Study was not acceptable. Therefore, Alder Reservoir, as evaluated in this study, is the higher-elevation 56,000 acre-foot reservoir considered in the Pre-Feasibility Study. Figure 1-1 presents an overview of the preferred storage alternative.

The preferred storage project would provide a substantial new water supply that can be accessed for out-of-stream or instream use anywhere within WRIA 31 or in WRIAs downstream of it, via diversion from the Columbia River. The preferred project would put water into storage and establish mitigated water rights for use of the stored water.

The identified potential benefits of the preferred storage project are substantial and include:

1. Sustain existing groundwater-supplied irrigation by using source exchange (using stored surface water in lieu of groundwater) and/or ASR to reverse the ongoing groundwater overdraft in western Horse Heaven.

2. Address interruptible water rights in the McNary Pool and downstream by providing mitigation water to offset their consumptive use during times when Columbia River instream flow minimums are not met.
3. Achieve regional economic development by making available new irrigation water supplies that would allow additional higher-value crop acreage to be brought into production.
4. Improve aquatic habitat within the lowermost reaches of Alder Creek and Switzler Canyon, downstream of the proposed reservoirs, including potentially creating thermal refuge for migrating salmonids in the mainstem Columbia River. The released water would also marginally improve instream flows in the mainstem during the critical months of July and August.
5. Maximize use of existing irrigation infrastructure to the extent practical, to reduce project capital cost.

Based on the outcome of the pre-feasibility assessment and discussions with Ecology's OCR staff, the WRIA 31 Water Resource Planning and Advisory Committee (Advisory Committee) applied for a grant from OCR to conduct a phased appraisal-level assessment with a goal of better defining the technical, permitting, and economic feasibility of the preferred storage project. In February 2011, Ecology's OCR and the lead agency for WRIA 31 watershed planning, Klickitat County, executed grant number G1100215 to conduct the appraisal assessment.

1.1 Phased Appraisal Approach

The 2010 pre-feasibility assessment identified no fatal flaws with the preferred project based on available information, but acknowledged that additional evaluation of specific items would be needed to more accurately define the project viability prior to proceeding to design phase. In structuring the grant for the appraisal assessment, OCR indicated that a more refined fatal flaw analyses needed to be done to indicate whether or not each surface reservoir appears viable, before proceeding with more detailed engineering/costing exercises. For the purposes of this assessment, a fatal flaw is a physical condition of the reservoir setting which is judged to make it infeasible to proceed with the proposed storage project, in terms of ability to either permit or construct the project. Therefore, the appraisal-level assessment was organized in the grant into two phases:

- **Phase 1** focuses primarily on more detailed evaluation of potential fatal flaws with the proposed surface reservoirs – Alder Reservoir and Switzler Reservoir. It also includes evaluation of the potential to integrate pumped storage into the project as a means to offset project capital costs (by bringing in project partners), as well as outline concepts for project water right permitting, administration (governance), and funding by which the preferred storage project would make available new water supplies. Finally, Phase 1 includes limited assessment of ASR, namely addressing a regulatory approach for applying ASR to irrigation use (i.e., non-potable beneficial use), since ASR compliance with water quality regulations remains a potential flaw in terms of its cost-effectiveness; and

- **Phase 2** would proceed if fatal flaws are not identified in Phase 1, and would involve refining the engineering assumptions for surface reservoir configuration and construction, and updating the current project cost estimates accordingly.

The findings and recommendations from each phase will be presented in a report specific to that phase.

1.2 Organization of Phase 1 Report

This Appraisal Assessment Phase 1 report presents the methods, findings, and recommendations from the Phase 1 fatal flaw analysis for the Alder and Switzler Reservoirs and, based on that, a recommendation to proceed with Phase 2 engineering analysis of the Switzler Reservoir.

The discussion of water right permitting, administration, and funding concepts will be presented in the Phase 2 report, since more refined project cost estimates will then be available from the Phase 2 analyses. The refined cost estimates, in turn, substantially affect project funding scenarios and the categories of water use that the stored water could most reasonably supply (e.g., new irrigation supplies, new municipal supplies, address existing interruptible water rights, etc.).

In addition, the ASR regulatory approach information is distinct from the surface reservoirs fatal flaw analyses, and will be presented under separate cover.

Subsequent sections of this Phase 1 report are as follows:

- **Section 2**: Assessment for integrating pumped storage into the preferred surface storage project (Alder and Switzler Reservoirs);
- **Section 3**: Fatal flaw assessment for Alder Reservoir, including assessment of geologic stability, channel geomorphology, aquatic habitat, terrestrial habitat, and archaeological resources;
- **Section 4**: Fatal flaw assessment for Switzler Reservoir, including assessment of geologic stability, channel geomorphology, aquatic habitat, terrestrial habitat, cultural resources, and water quality (predictive);
- **Section 5:** Conclusions and Recommendations from the Phase 1 Assessment; and
- **Section 6:** References cited in this report.

Appendices A and B include photographs taken in Alder Creek and Switzler Canyon, respectively, during the September 2011 field reconnaissance for this Appraisal Assessment

2 Assessment of Pumped Storage Potential (Alder and Switzler Reservoirs)

2.1 Description of Pumped Storage

As part of this study, a preliminary “fatal flaw” assessment of the potential for integrating pumped storage into the proposed storage project was completed. Pumped storage would involve using the water stored in the proposed reservoirs at Alder Creek and Switzler Canyon for power generation. The most likely scenario would involve configuration of the reservoir with pumping/generation units to supply water to the reservoir and generate power when water is discharged from the reservoir. Pumped storage generates power by moving water between two reservoirs at different elevations. Pumped storage projects generate revenue by selling power during high demand (and higher cost) periods while using lower cost power for pumping to fill storage reservoirs. When power demand is low or power availability is high, water is pumped from the lower reservoir to the higher reservoir. When power demand is high or power availability is low, water stored in the upper reservoir is released through hydroelectric turbines to generate power. In the case of the proposed Alder Reservoir, the lower reservoir would be the John Day pool on the Columbia River. In the case of the proposed Switzler Reservoir, the lower reservoir would be the McNary pool on the Columbia River.

Pumped storage can be used to balance the variability in wind power generation. In the Pacific Northwest, wind generation has substantially increased in recent years and steady increases are forecasted for the near future due to the increased demand for clean, renewable energy and tax incentives that make wind generation profitable, even when market prices for other energy sources are low. Information on wind generation provided at the Bonneville Power Administration (BPA) internet site (BPA, 2011) indicates that in 2008, less than 2,000 megawatts (MW) of renewable power had been connected to the BPA energy transmission grid. In 2010, more than 3,000 MW were connected. BPA forecasts indicate that approximately 6,800 to 9,000 MW of renewable energy will be connected to the BPA grid by 2017.

Although wind generation increases power supply, wind generation is highly variable due to rapidly changing weather conditions. For example, BPA recorded variations of 1,200 MW in wind generation from one day to the next in January 2009 (Mainzer, 2009). The variability in generation creates significant challenges for power generation facilities located on the Columbia River as they are now being used, to the extent possible, as peaking power generation facilities. However, the hydroelectric facilities have limitations for use as peaking power generation facilities because of their capacity, required flow releases through the dams, and issues with dissolved gas generation downstream of the dams. Consequently, pumped storage is now being considered as an option for integration with wind generation to provide better system reliability and response to energy demands. During times of low energy demand or when high wind generation results in surplus energy, low cost energy can be used to pump water from the Columbia River to the proposed storage facilities. During times of high energy demand or when wind generation is low, water can be released through hydroelectric turbines for additional power generation.

There is growing interest in creating new power generating sources, such as pumped storage, to integrate with and help balance power generation. Private developers and power companies are continuing to study pumped storage projects throughout the northwest. For example, Klickitat Public Utility District No. 1 (KPUD) has indicated that they are studying the potential for a pumped storage project that would generate 1,000 to 1,200 MW to balance the variability of power generated at wind turbine farms recently developed in the Columbia River Gorge. Legislation passed by the Washington State Senate (SSB 6044) during the current legislative session would allow KPUD to supply water authorized by existing water rights for a pumped storage generating facility. Other projects are in various stages of development in the Columbia Basin.

This assessment of the potential for integration of pumped storage as part of the WRIA 31 water storage project represents a very preliminary evaluation intended to identify fatal flaws and, if warranted, recommend steps for additional study.

2.2 Hydroelectric Potential

Hydroelectric generation potential is estimated according to the following equation:

Power = Head x Flow Rate x Efficiency / 11.8

where:

Power = Electric power generation, measured in kilowatts (kW).

Head = The difference between the water surface elevation in the reservoir and the elevation at the power plant, adjusted for pressure losses sustained in the delivery penstock or tunnel, measured in feet. For this study, pressure losses were assumed to be 10 percent of the total static pressure head.

Flow Rate = The amount of water discharged through the power plant, measured in cubic feet per second (cfs).

Efficiency = The ratio of power generated by a hydroelectric plant to the potential energy of the water stored in the reservoir. For this study, an efficiency of 85 percent was assumed.

11.8 = Unit conversion, of Head (feet) and Flow (cfs) to kW.

As part of this evaluation, the hydroelectric potential was estimated for each reservoir site. As noted above, hydroelectric potential is directly related to the flow rate released from a reservoir. Higher flow rates result in greater hydroelectric potential. Higher flow rates also require larger pumping, generation, and conveyance equipment, resulting in higher project capital costs. This study does not attempt to recommend the configuration or size of pumped storage facilities that would be preferred by a pumped storage project developer. Rather, this evaluation assumes that facilities would be designed to generate 250 MW of power at each storage site when the reservoirs are full, just to establish a baseline for the discussion on the cost and feasibility of integrating pumped storage.

2.2.1 Alder Reservoir

Figure 2-1 plots the potential hydroelectric capacity of a generating facility over a range of discharge rates for power generation using water stored in the proposed Alder Reservoir. Based on an assumed maximum water surface elevation of 680 feet and a low water surface elevation of 480 feet, the assumed operating head for power generation would range from 214 feet to 414 feet. An efficiency of 85 percent was assumed.

The potential generating capacity at the proposed Alder Reservoir could be as high as 250 MW at full reservoir capacity if facilities were sized to convey up to 9,300 cfs from the reservoir to the Columbia River. We estimate that a 28-foot-diameter penstock or a combination of smaller penstocks would be required to convey that flow rate at a maximum velocity of 15 feet per second (fps).

2.2.2 Switzler Reservoir

Figure 2-2 includes a plot of the potential hydroelectric capacity of a generating facility over a range of discharge rates for power generation using water stored in the proposed Switzler Reservoir. Based on an assumed maximum water surface elevation of 780 feet and a low water surface elevation of 450 feet, the assumed operating head for power generation would range from 100 to 430 feet. An efficiency of 85 percent was assumed.

The potential generating capacity at the proposed Switzler Reservoir could be as high as 250 MW at full reservoir capacity if facilities were sized to convey up to 8,950 cfs from the reservoir to the Columbia River. We estimate that a 28-foot-diameter penstock or a combination of smaller parallel penstocks would be required to convey that flow rate at a maximum velocity of 15 fps.

2.2.3 Potential Annual Power Production

The operation of a pumped storage project capitalizes on the difference in the cost of power that can be sold during peaking periods and the cost of power used for pumping during off-peak power periods. A pumped storage plant designed to take advantage of the cost differences on a daily basis would likely be operated for a period of 8 to 10 hours per day, during peak power energy use hours. For a 250-MW pumped storage generation station, the total annual power generation would be approximately 730,000 MW-hours (MW-hr), if the power station operated 8 hours per day year-round. In the case where a pumped storage project is used to supply power to balance wind generation, the plant may need to operate for more than 1 day, which would result in more power being produced on an annual basis.

On a daily basis, the difference between peak and off-peak power is forecast to range from $5 per MW-hr to $26 per MW-hr during the next 20 years, with an average of approximately $12 per MW-hr [Northwest Power and Conservation Council (NWPCC), 2010]. Based on those forecasts, the projected value of power produced would average $8.76 million (730,000 MW-hr times $12/MW-hr) per year. If the developer of a pumped storage project owned other generation resources, the cost difference and resulting value of power generated could be much larger, as they presumably could fill the reservoir using lower cost power.

2.3 Summary of Potential Costs, Operational Challenges and Benefits

The *WRIA 31 Storage Pre-Feasibility Assessment Report* (Aspect and Anchor QEA, 2010) includes preliminary opinions of probable costs for the preferred storage project. Costs developed for the proposed storage reservoirs, excluding pumping and conveyance required to deliver water to the reservoirs, are summarized in Table 2-1.

Table 2-1
Unit Cost – Proposed Storage Reservoirs (Storage Only)

Reservoir	Total Storage Capacity (Acre-feet)	Planning Level Capital Cost ($)	Planning Level Unit Cost ($/Acre-foot)
Alder	56,000	$124,000,000	$2,220
Switzler	44,000	$175,000,000	$3,940

1. Source: *WRIA 31 Water Storage Pre-Feasibility Assessment Report (Aspect and Anchor QEA, 2010)*

Costs were also developed for the overall project, including pumping and conveyance facilities. One scenario assumes that pumping and conveyance would take advantage of existing infrastructure to reduce cost. Another scenario assumes all new pumping and conveyance facilities. Table 2-2 summarizes the opinions of project costs developed for the scenario where all new pumping and conveyance facilities are installed.

Table 2-2
Unit Cost – Proposed Storage Projects With All New Pumping and Conveyance Facilities

Reservoir	Total Storage Capacity (Acre-feet)	Planning Level Capital Cost ($)	Planning Level Unit Cost ($/Acre-foot)
Alder	56,000	$256,925,000	$4,600
Switzler	44,000	$273,056,000	$6,150

1. Source: *WRIA 31 Water Storage Pre-Feasibility Assessment Report (Aspect and Anchor QEA, 2010)*

Integration of pumped storage would result in much higher costs for pumping and conveyance facilities because those facilities would need to be designed to move much larger volumes of water on a much shorter (daily) time scale, rather than providing just enough capacity to refill the reservoir once annually through a 5- or 6-month period. A combined pumping/power generation facility would likely be required. Additional costs would include construction of a powerhouse, penstocks, generating equipment, a river intake, a switchyard, transformers, transmission lines, and other equipment required to generate and deliver power to the BPA power grid.

Recent opinions of probable cost were developed for the *Summary Report, Investigation of Multiple Benefit Water Storage Project in the Mid Columbia* (HDR/DTA, 2011), which was prepared for Chelan PUD and Ecology to evaluate the feasibility of pumped storage alternatives in the mid-Columbia River Basin near Wenatchee, Washington. The opinion of total construction costs, including the cost of storage facilities, conveyance facilities, and power-generating facilities, as outlined in the 2011 report, range from $1.513 million per MW to $2.850 million per MW. The installed capacities of the alternatives that were identified in the report ranged from 976 MW to 3,784 MW. Static heads ranged from 667 feet to 2,645 feet.

As noted previously, a pumped storage project installed in Alder Creek Canyon or Switzler Canyon would have less static head to generate power and would likely have less installed power generation capacity than those studied in the 2011 report prepared for Chelan PUD and Ecology. Thus, the unit cost for the proposed Alder Reservoir and/or Switzler Reservoir projects with pumped storage integration would likely be high relative to the costs outlined for the storage alternatives in that study. Assuming an average construction cost of $2.8 million per MW, which is at the high end of the range for the alternatives outlined in the study cited above, the total cost of a 250-MW pumped storage project (including storage) would be approximately $700 million. Based on this cost, the estimated cost of the storage project with integration of pumped storage would be approximately $576 million higher for the proposed Alder Reservoir and $525 million higher for the proposed Switzler Reservoir. The power production may result in estimated annual revenues of $8.76 million.

A more detailed study would be required to more clearly identify the costs and potential benefits associated with integration of pumped storage.

However, based on this preliminary review of pumped storage integration, discussions with a local power provider, KPUD, and review of available studies, it is unlikely that the benefits of pumped storage would justify the cost of integrating pumped storage into either of these projects. The *Summary Report, Investigation of Multiple Benefit Water Storage Project in the Mid Columbia* (HDR/DTA 2011) recommended further study of three alternatives for pumped storage projects in the mid-Columbia River Basin near Wenatchee. The projects that were recommended for further study all had static lifts of more than 1,200 feet. The smallest project recommended would have an installed capacity of 769 MW. The estimated unit costs for the recommended projects would range from $1.7 million per MW to $2.1 million per MW. The static head available for generation for the proposed Alder Reservoir and Switzler Reservoir would be much lower. As a result, the installed capacities would be lower, unless larger conveyance facilities were installed to allow for a higher release flow rate from the reservoir.

KPUD has been studying pumped storage in more detail with the goal of integrating pumped storage to balance wind generation from new wind turbine farms in the Columbia River Gorge. KPUD has suggested that their study of pumped storage indicates that a static head of 1,000 feet or more is needed to make pumped storage feasible (Mosbrucker, 2012). Overall, the initial reaction from KPUD was that the elevation difference between the proposed Alder and Switzler Reservoirs and the Columbia River is not large enough to make integration of pumped storage a viable option for this project.

Other challenges associated with integration of pumped storage for the proposed storage project would include the following:

- **Reservoir Operation:** If the project was designed without pumped storage, operations would generally require filling through the winter and release through the summer to mitigate for water use elsewhere. If pumped storage was included, operations would result in large daily fluctuations in storage. Reservoir operations would need to optimize the benefits of pumped storage while also meeting the seasonal needs for water demand, which would be much more complicated than simply operating the reservoirs to meet water demand.

- **Operation and Maintenance of Pumps and Conveyance Facilities:** A pumped storage project would require larger pumping and conveyance facilities, as well as power generation and transmission facilities. The larger, more extensive infrastructure would be more difficult and expensive to operate and maintain.

The primary benefit of integrating pumped storage as part of the project would be the potential to deliver energy at peak energy prices during times of high demand and low power availability. Another key benefit would be that inclusion of pumped storage could attract funding for infrastructure capital costs from other project partners, such as a pumped storage project developer. These other potential funding sources would not likely be interested in funding a project solely focused on water storage. The pumped storage would also have the potential to balance the variability of wind-generated energy supplied to the grid at nearby wind turbine farms.

2.4 Recommendation regarding Pumped Storage Integration

Although there is interest in developing pumped storage to balance the variability of power generated by nearby wind turbine farms, this preliminary evaluation indicates that integration of pumped storage is likely not feasible due to cost. Review of available information and discussion with a local power provider indicate that the proposed Alder Reservoir and Switzler Reservoir would not provide enough static head and potential generating capacity to justify the cost of including pumped storage facilities as part of the WRIA 31 storage project.

Consequently, it is recommended that the option of integrating pumped storage not be considered as part of future study of the project, unless a pumped storage project developer expresses specific interest in one of the proposed reservoir sites.

3 Fatal Flaw Assessment for Alder Reservoir

This section presents our assessment of potential fatal flaws for the proposed Alder Reservoir, culminating in a recommendation for whether it should proceed into the Phase 2 engineering assessment. The fatal flaw assessment is based on the information collected in the course of this Phase 1 work, subject to the available budget and schedule. Future collection of additional information could change the assessment and conclusions regarding fatal flaws.

The subsequent subsections address the following technical disciplines relevant to permitting, constructing, and operating the proposed Alder Reservoir:

3.1 Geologic Hazards and Slope Stability

3.2 Channel Geomorphology

3.3 Aquatic Habitat

3.4 Terrestrial Habitat

3.5 Cultural Resources

Because Alder Reservoir is concluded to be fatally flawed based of landslide hazards, a predictive water quality assessment was not conducted for it. Based on the collective available information generated in Sections 3.1 through 3.5, Section 3.6 presents the conclusions and recommendation regarding Alder Reservoir.

3.1 Geologic Hazards and Slope Stability

A preliminary analysis of geologic hazards including fault-rupture hazards and reservoir slope stability was conducted for the proposed Alder Reservoir site. The analysis consisted of compilation and review of geologic information on the site, conducting a geologic site reconnaissance to review existing conditions including existing slope stability, and a fatal-flaw-level assessment of seismicity-related hazards including fault rupture, slope stability hazards, and assessment of geological impacts to the reservoir and surrounding area that could occur through operation of the reservoir. The site geologic reconnaissance was conducted on September 29, 2011, by a licensed engineering geologist from Aspect Consulting.

Results of the analysis indicate that there are no known fault-rupture hazards or other seismic hazards within the dam or reservoir footprint that cannot be mitigated during design and construction. However, there are a significant number of existing, mostly ancient, landslides at the site. In addition to the potential for re-activation of existing landslides within the reservoir, potential exists for initiation of new landslides that could extend outside of the area of the reservoir, and into areas currently used for agriculture and grazing. Additional data collection and analysis would be required to further define the probable extent of slope movement under reservoir operating conditions (repeated reservoir filling and emptying), should Alder Reservoir proceed into later design phases.

There are no cost-effective technologies for reducing the probability of reactivating old landslides or triggering new landslides at the scale that would be required at this site. Mitigation would consist of some combination of designing the reservoir facilities and operations to accommodate the hazards, establishment of high risk setback areas, and/or compensation for loss of use of property in the event that landslide damage occurs.

Because of the extent and size of existing landslides within the reservoir area, the potential for these landslides to re-activate during reservoir operations, the potential for landslides spreading into and damaging adjacent property, and the absence of cost-effective methods for reducing the impacts, we consider the landslide hazards to be a fatal flaw for the Alder Reservoir site.

A summary description of existing site conditions and potential impacts and mitigation for Alder Reservoir is presented below.

3.1.1 Current Understanding of Conditions

The Alder Creek drainage lies within the Columbia Basin physiographic province, an area of broad valleys with gently dipping surfaces separated by moderately to steeply dipping linear ridges. Horse Heaven Hills forms the ridge to the north of the Alder Creek drainage and the Columbia Hills forms the ridge to the south. These east-west trending ridges rise up to a thousand feet or more above the valley bottom.

Where Alder Creek flows generally southward across the valley floor between these ridges, it has incised a canyon about 200 to 250 feet deep and 2,000 to 3,000 feet wide. Where the canyon cuts through the Columbia Hills before it discharges to the John Day Pool of the Columbia River, it is about 600 feet deep. The walls of the Alder Creek canyon range from cliffy and benched slopes to moderately steep and undulating surfaces that dip an average of 15 degrees or 28 percent. Existing topography is presented on Figure 3-1.

The proposed Alder Reservoir configuration includes an earth-fill dam site located about one mile upstream of the confluence of Sixprong Creek and Alder Creek. The crest of the dam would lie at about elevation 690 feet, with an operational pool elevation at about 680 feet, creating a reservoir about 220 feet deep at the dam. The reservoir would extend about four miles from the dam with the upstream end located near the confluence of Tule Canyon and Alder Creek (Figure 3-1). Operational water levels would vary seasonally from about elevation 680 feet to 480 feet, resulting in reservoir drawdowns of about 200 feet.

Regional Geology

The nature of the canyon at the reservoir and dam site and the overall stability of the site are functions of site geology, climate, and groundwater. The Columbia Basin is underlain by many, stacked basalt flows, each tens to hundreds of feet thick. The basalt flows are separated by rubbly to clayey flow contacts and locally by sedimentary interbeds that may be many tens of feet thick. These Miocene-age 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.

Tectonics and Geologic Structures

The entire Columbia Basin has been subjected to tectonic compression and rotation at least since the time of the placement of the basalt flows between about 17 and 6 million years ago, and the compression and rotation continue today. As the regionally extensive flows of basalt were being erupted and were cooling, they were also being folded by these compressive stresses, creating what is called the Yakima Fold and Thrust Belt. The Yakima Fold and Thrust Belt is a series of steep, asymmetric, anticlinal folds and associated thrust faults, separated by broad, gently dipping synclines. Typically the limbs of the synclines dip a few to about 10 degrees while the limbs of the anticlines are more steeply dipping, with sections that may be vertical or even overturned.

The mapped nearest anticline to the site forms the Columbia Hills, about two miles south of the proposed dam site. An unnamed synclinal fold associated with the northern limb of this anticline lies about 2,000 feet south of the proposed dam site (Figure 3-2). The next nearest anticline to the site forms the Horse Heaven Hills, which is about 13 miles northwest of the site (north of the map view shown on Figure 3-2).

Fault and Seismicity Hazards

The potential for strong shaking and ground rupture is a consideration for siting, design, and operation of any dams and reservoirs within the region. Seismic hazards for a site are assessed by identifying nearby earthquake- and rupture-capable faults, and generating probability and ground acceleration maps for a site by combining the individual hazards from the known faults near the site.

The compressive stresses that formed the Yakima Fold and Thrust Belt are still acting on the area. Anticlines with greatest vertical relief and horizontal shortening are typically thrust-faulted, in which older strata are pushed up and over younger strata. Many of the faults in the Yakima Fold and Thrust Belt have had movement along them during the Quaternary Period (the last 1.8 million years). There has also been movement on some Yakima Fold and Thrust Belt faults in the Holocene Epoch (the last 11,000 years). If a fault has been active in the Holocene, it is generally believed to be capable of slipping and causing ground shaking in the present and future. Within several hundred miles of the proposed Alder Reservoir, there are a number of these faults that are believed capable of producing strong ground shaking.

No faults have been identified within the footprint of the proposed Alder Reservoir and dam site. The nearest known faults to the site identified by the U.S. Geological Survey (USGS, 2012a) are about one to two miles south of the site along the north flank of the Columbia Hills anticline. While there is no direct evidence of movement on this fault during the Quaternary Period or Holocene Epoch, collectively, local and regional structural relations suggest that exposed and buried faults in the Columbia Hills link to earthquake-capable faults in the subsurface and that the east-trending folds may be active. Based on the lack of direct evidence of Quaternary deformation, however, the USGS regards this fault as having lower certainty or risk of earthquake hazard (it is considered a Class B fault).

The nearest faults that the USGS considers potential earthquake sources (Class A faults) (USGS, 2012b) include reverse or thrust faults on Toppenish Ridge, which lies about 30 miles northwest of the site, and along the Rattlesnake Mountain trend, which lies about 30 miles northeast of the site.

Based on the distance to faults identified as those with potential to rupture, the fault rupture hazard at the site is considered low. At this time, there are insufficient site data to evaluate other potential seismic hazards such as liquefaction of foundation areas.

Site Geology

The basalt flows that have been mapped at the site area, as compiled by Schuster (1994) and the Washington Division of Geology and Earth Resources (WDGER, 2012) include, from top down, the Elephant Mountain, Pomona, and Umatilla Members of the Saddle Mountains Basalt. These basalt members are typically several tens to a hundred or more feet thick. 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 closely more 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 in standing water. The structure of the basalt flows and the nature of the internal fractures is a significant factor in the geologic stability of the site and morphology of the slopes.

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. These sediments consist of clay, silt, and sand and gravel and regionally range from absent to up to several hundred feet thick. These sedimentary interbeds are collectively termed the Ellensburg Formation. In the Alder Creek area, water well logs indicate that individual interbeds are up to about 70 feet thick. These interbeds are significant factors in the slope geomorphology and potential slope stability issues associated with the canyon walls. These sedimentary interbeds and the rubbly basalt flow tops and bottoms that bound them also form the major regional water supply aquifers within the region.

Geologic Units

Review of geologic maps and water supply well logs from the site area suggests that the site geology consists of the following units, from generally younger to older. The young units are all recent (Holocene or latest Pleistocene), and the older units are Miocene age volcanic and sedimentary rocks. These units consist of the following:

- Loess - Composed of windblown silt and fine sand that was deposited largely during the last glaciation and late glacial flooding of the region. Loess is mapped throughout much of the uplands outside of the Alder Creek canyon, and some of the surficial soils that support agriculture in the area are composed of loess.

- Recent Alluvium – Composed of water-worked silt, sand, and gravel within channels of modern drainages. Recent alluvium occurs within the broad bottom and meandering channel and floodplains of Alder Creek and its major tributaries including the mouth of Tule Creek.

- Landslide Deposits – Composed of rock and soil material transported downslope by mass wasting and landslide processes. Landslide deposits occur throughout much of the Alder Creek canyon, and are mapped as covering roughly half of the slopes exposed in the canyon.

- Outburst Flood Deposits – Composed of sand and gravel where Pleistocene glacial outburst floods from glacial Lake Missoula deposited sand- to boulder-sized sediment. These coarse-grained facies are called the Pasco Gravel. A fine-grained facies called the Touchet Beds is composed of silt and fine sand that was deposited by settling from turbid floodwaters that were impounded in basins and side canyons. Except where incised by drainages, this fine-grained glacial flood unit covers most of basalt bedrock across the uplands outside of the canyon. It forms most of the surface soils that support agriculture in the vicinity of the site.

- Elephant Mountain Basalt – This member of the Saddle Mountains Basalt is the upper flow that is prevalent throughout the Alder Creek reservoir area. It is noted on nearby water supply well logs to be about 80 to 100 feet thick and may be composed of several distinctive flows. It occurs as cliffs and ledges near the top of the Alder Creek canyon, as the broad slopes beyond the canyon, and on the flanks of the Columbia Hills.

- Rattlesnake Ridge Interbed – An Ellensburg Formation sedimentary unit that lies between the Elephant Mountain Basalt and the Pomona Basalt. This unit is noted in water well logs to be 45 to 70 feet thick. It is noted to consist primarily of clay, and lesser amounts of fine sand. 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. It was noted to be caving in one well log. Clayey interbeds of this type are typically easily eroded when exposed, and thus do not form surface exposures (exposures are typically limited to road cuts, etc.).

- Pomona Basalt – This is the lower bedrock basalt unit exposed in the canyon section. It is noted on well logs to be about 150 to 160 feet thick and would extend below the level of Alder Creek. Where not covered by landslide debris, it occurs at the site as a lower cliff- and ledge-forming unit within the canyon section, and locally on the dipping flank of the Columbia Hills.

- Selah Interbed – A nearby water well that penetrated the Pomona Basalt encountered clay and sandstone at least 30 feet thick. Regional stratigraphic analysis suggests that this is the Selah Interbed. This would lie well below the canyon bottom, but could be a significant consideration for dam design.

Hillslope Geomorphology

Alder Creek canyon exhibits many discontinuous basalt ledges and outcrops up to 1,000 feet in length and up to 300 feet wide that are generally separated vertically and laterally from one another by moderately steep slopes of non-stratified soil and rock debris. In several locations within the reservoir footprint, meandering Alder Creek has cut into the toe of the slope exposing stratified but deformed and slickensided sedimentary deposits, and chaotically mixed soil with angular basalt rocks suspended within a matrix of silt, clay, and fine sand (a diamict). Slickensides (sheared and polished surfaces) were abundant within some of these deposits, indicating shearing and slippage. In places, these deposits are standing vertically in stream cuts up to several tens of feet high, but are above creek level and are not currently exposed to saturated conditions.

The overall nature of the disturbed and sheared sedimentary deposits and diamict suggests that they are landslide deposits derived from failure of the Rattlesnake Ridge sedimentary interbeds and/or possibly the silty Touchet Beds that lie on the uplands outside the canyon, above the basalt. The irregular nature of the basalt outcrops below the thick cliffs of the Elephant Mountain Basalt suggests that the exposed basalt outcrops on much of the lower and middle slopes are large blocks up to several hundred feet wide by up to 1,000 feet long that broke away from the cliffs above. These basalt blocks are interpreted to be sliding downslope on a bed of weak clay derived from weathering and failure of the Rattlesnake Ridge sedimentary interbed. Figure 3-3 is a photograph of landslide benches near the proposed right dam abutment of Alder Reservoir, with an interpretation of the subsurface geologic units and their relationship to the landslides.

Large translational landslides have been observed elsewhere throughout the Columbia Plateau region. They typically occur as failure planes on dipping or exposed clay beds that occur between the highly fractured but largely intact basalts flows. Analyses of the stability of landslides on weak clayey soils at other sites suggests that slides may occur on slopes of as gentle as 3 degrees, or in areas where there is an absence of lateral support (buttressing) for rock units above these weak soils. Thus, the prevalence of landslides within the Alder Creek area appears to be a consequence of the relative thickness and weakness of the clayey beds in relation to the thickness of the Elephant Mountain basalt which lies above it, and open space within the canyon for these soils to slide into.

The majority of the canyon slopes do not appear to have active slide movement. No sharp scarps or tension cracks indicating active or recent movement were observed except where there is ongoing erosion of the toe of an existing landslide deposit by meandering Alder Creek. The degree of rounding and weathering of the landslide surface suggests great antiquity for the slides. If the slides are still active, they appear to be moving very slowly.

The two most likely events to have precipitated these landslides were: 1) periods of significantly greater precipitation than now, which could have occurred during the Pleistocene ice age climate, resulting in higher groundwater levels and more seepage and weathering of the sedimentary interbeds, combined with more rapid canyon incision; or 2) immersion by the glacial outburst floods that covered the area in floodwaters numerous times on scales of decades to centuries apart during the Pleistocene, ending about 12,000 years ago.

3.1.2 Anticipated Issues for Permitting and Construction

Construction of the Alder Reservoir will need to consider the impacts of geology and landslides on the project and surrounding areas. Specifically, the following issues should be considered for construction, operation, and permitting:

- The embankment areas and foundation of the dam need to be geotechnically stable, or stabilized in order to construct the dam and have it provide safe service during design storm and earthquake events. The presence of landslide deposits within the embankment footprint suggests that some stabilization or ground improvement would be required to develop a stable foundation and abutments.

- If it were possible or feasible to remove weak or potentially leaky landslide deposits within the dam footprint, it could still require improvement of the undisturbed sedimentary interbeds that remain between the Elephant Mountain and Pomona Basalts. The presence of sand layers or zones within the interbed suggests that seepage through this unit could occur, potentially decreasing stability of the embankment or slopes downstream of the embankments. Ground improvement (likely by constructing a grout curtain) could be required to reduce leakage to acceptable levels.

- The stability of the existing landslide deposits would decrease during immersion by the reservoir. Although we do not have the site-specific subsurface data to produce a numerical analysis of the stability of the landslide deposits, it is our opinion that they would likely show a small margin of safety under existing conditions and would show failure under saturation from reservoir immersion. The most likely mode of failure would be renewed creep and slow sliding.

- Another factor to be considered is the impact of rapid water level drawdown of the proposed reservoir. Drawdowns rapid enough to allow high pore pressures to remain in soils could decrease the stability of the deposits, creating the potential for rapid failures or debris flows.

- Landslides of a significant part of soil on the canyon walls would slightly reduce the depth of the reservoir, and potentially reduce the reservoir volume if landslide failures were to propagate above the shoreline.

- The potential for earthquake-triggered landslides and landslide-induced large waves within the reservoir would need to be studied and addressed.

- Turbidity of water within the reservoir could increase following landslides into the reservoir.

- Subaqueous landslide debris flows, which can travel long distances underwater on very gentle gradients, would be a design and operations consideration. If the dam was designed to draw from the bottom of the reservoir to reduce outlet water temperature, there is potential for impacts to outlet works by subaqueous debris flows.

- If the landslides were to re-activate, there is potential for them to propagate upslope or inland, beyond the current edges of the canyon, effectively enlarging the canyon and losing portions of the adjacent uplands properties. Most of the land adjacent to the reservoir and canyon is used for grazing or agriculture, including center-pivot irrigated plots and vineyards. An air photo showing recent land use around the reservoir area is presented on Figure 3-4. The economic impacts of loss of this land and road and other infrastructure would need to be considered. Should the Alder Reservoir project proceed, we expect that a more thorough evaluation of the stability of slopes and the impacts of reservoir operation on slope stability will be completed as part of future studies prior to project permitting, design, and construction.

3.1.3 *Potential Mitigation Opportunities*

The geotechnical elements introduced by constructing a dam on landslide-impacted slopes can be mitigated during design and construction. It could require extensive excavation and ground improvements to provide adequate foundation support and cutoff from seepage.

In our opinion, there is no feasible method of preventing reactivation of landslides in and around the reservoir during filling and operation. Mitigation would require planning for long-term decreases in reservoir depth or capacity, potentially turbidity concerns that could impact water quality, and potentially operations of the reservoir.

Impacts from lateral expansion of landslides beyond the reservoir could be mitigated by either establishing a high-hazard area setback or buffer zone around the reservoir, or by compensating landowners for damage or loss of use caused by landslide activity.

3.2 Channel Geomorphology Assessment

An appraisal-level assessment of geomorphology and sediment transport of the portion of Alder Creek Canyon potentially affected by the proposed water storage facilities was performed based on existing data and limited field reconnaissance. Several locations along the creek alignment in the vicinity of the proposed Alder Reservoir were evaluated and observed with respect to the presence of surface water flow, channel size and type, and sediment load and characteristics. The following sections summarize our observations of existing conditions and potential impacts to the Alder Creek channel that would result from implementation of the proposed reservoir project.

3.2.1 *Current Understanding of Conditions*

The proposed reservoir would be created by constructing a dam near River Mile (RM) 4.2 (Figure 3-5). The proposed reservoir would extend up to the Cow Camp, near RM 9. Our understanding of existing conditions is based on field observations of Alder Creek Canyon between approximately Hale Road near RM 7 and the confluence with the Columbia River. Field reconnaissance was performed in late September 2011.

For the purposes of describing potential downstream impacts of the proposed reservoir, five geomorphic reaches were delineated between the proposed dam and the mouth of the creek. The reach extents were chosen based on distinct geomorphic characteristics: channel pattern, sediment size, and geologic controls such as channel grade and canyon confinement. The proposed reservoir project would likely affect these reaches in different ways or at different magnitudes. Observations of the Alder Creek channel are presented below, followed by potential impacts to these areas under the proposed conditions. The reach extents and other relevant locations pertaining to the assessment are shown on Figure 3-5, and photographs taken during the field reconnaissance are included as Appendix A.

Site Observations

Upstream of RM 4.2

Upstream of the proposed reservoir, a brief reconnaissance was performed between Tule Canyon (Cow Camp) near RM 9, and the intersection of Alder Creek Road and Hale

Road near RM 7. The canyon upstream of the proposed dam was observed by entering the canyon near Daniels Road on the east side of Alder Creek Canyon near RM 4.5.

Upstream of the proposed dam, the Alder Creek channel and tributary channels did not contain surface water flow at the time of field observation. The channel bed was primarily composed of an armor layer of cobbles with boulders in some places; water marks were present 2 to 3 inches from the base of the rocks. Some areas of the channel were composed of dry sandy and gravelly subarmor, and other areas had a cracked mud bottom (Appendix A, Photograph 1).

The channel is relatively wide and flat through much of its length. Evidence of cattle grazing was apparent throughout the canyon. In many places the channel displays a braided geometry with loose, sandy bars vegetated with low-lying sparse shrubs and grasses. Upstream of the Cow Camp, the channel alternates between wide, braided sections and slightly narrower sections that are slightly incised into older alluvium (Appendix A, Photograph 2). Accumulations of debris were observed in the floodplain near Tule Canyon that indicated relatively recent bank overtopping; debris was observed approximately 2 to 3 feet above the channel bed.

RM 4.2 to 3.0 (Reach 1)

From the proposed dam to approximately 1.2 miles downstream at Sally Spring, the Alder Creek channel could not be directly observed because of limited access and permissions. The channel was observed from the Alderdale Road (above the canyon) and on aerial photography. This reach of Alder Creek did not appear to contain surface water flow at the time of field observation, and the channel characteristics are similar to those described within the reservoir footprint, as noted for the reach of Alder Creek upstream of RM 4.2.

RM 3.0 to 2.7 (Reach 2)

Surface water was present in the channel downstream of Sally Spring during the field reconnaissance, where surface water flow was estimated based on visual observation to be approximately 5 to 10 cfs. Due to access constraints, the channel could not be observed closely from approximately RM 2.7 to the origin of the spring at RM 3.0.

Sixprong Creek is the primary tributary to Lower Alder Creek and joins Alder Creek approximately 1.5 miles downstream of the proposed dam (RM 2.7). Approximately 1/3 mile upstream of the confluence with Sixprong Creek, there is a natural pinch point in the canyon topography (Figure 3-5). Just downstream of this point the channel is relatively steep and contains several large boulders that form a step-pool configuration (Appendix A, Photograph 3). Under the current flow regime, it is not likely that these boulders can be mobilized by the creek during high-flow events and this feature may hold the elevation of the channel grade at this location.

Downstream of this point, the canyon widens somewhat, although the channel is typically incised several feet into the alluvium at the bottom of the canyon. In the heavily wooded area downstream of Sally Spring, large woody debris (LWD) loading in the channel and floodplain is high, including a large log jam accumulated on a standing mature tree, which splits the channel into two flow paths. LWD and boulders create pools in the channel, which alternate with steeper sections lined with boulder and cobble riffles. Along the left (east) side of the canyon, there is a high-flow channel that was dry during field observation but appeared to have conveyed surface water flow during the past year. Approaching the confluence of Sixprong Creek near RM 2.7, the channel becomes more influenced by beaver activity; occasional beaver dams were observed.

RM 2.7 to 1.8 (Reach 3)

The channel in Reach 3 was observed at several locations from Sixprong Road. Reach 3 is typically characterized by alternating slow-moving pools with locally steep cobble and boulder-lined riffles. The channel has a sandy, gravel subarmor with some fines and organics that have settled on the surface in the pool sections. The pools are held by large beaver dams that create up to 4-foot drops in the water surface elevation (Appendix A, Photograph 4). Approaching the bridge crossing at Sixprong Road (RM 1.8), the channel becomes slightly wider with a gravelly bottom and is less influenced by beaver activity (Appendix A, Photograph 5).

Overall, the channel planform appears to be relatively confined with little to no opportunity for channel migration. Throughout much of the reach, a narrow swath of low floodplain is present along the channel. The floodplain is vegetated with low-lying shrubs and groundcover, indicating relatively frequent inundation on the order of 1 or 2 years. This low-lying floodplain is flanked by a series of older, high alluvial terraces, colluvium, or the bedrock canyon wall.

RM 1.8 to 0.5 (Reach 4)

The channel was observed at several locations from Alderdale Road between the Sixprong Bridge crossing (RM 1.8) and the extent of the backwater from the Columbia River (RM 0.5). Throughout Reach 4 the canyon is relatively steep and narrow, and the channel is deeply incised into the surrounding terraces and steep canyon walls. The channel is typically single thread and plane bed (i.e., a channel with a single flow pathway and relatively uniform cross-section) with some locally steep, boulder-dominated sections (Appendix A, Photograph 6). The subarmor is composed of sand and gravel. A natural pinch-point in the canyon is located approximately 3/4 mile upstream of the mouth. Just upstream of this location the active channel is split into two flow paths; the eastern flow path was muddy at the time of field observation but did not contain surface water flow. The channels are separated by a high, disconnected floodplain.

RM 0.5 to 0.0 (Reach 5)

At approximately RM 0.5, geomorphic processes within the creek channel are dominated by the influence of backwater from the Columbia River at Lake Umatilla (John Day Pool). The channel is wide, slow moving, and contains relatively fine sediments that are able to settle on the bottom because of the slow velocities (Appendix A, Photograph 7).

Site Evaluation

This study assumes that the Alder Reservoir would be filled with Columbia River water by pumping during the winter and early spring. The water would then be released during the summer and early fall back to the Columbia River. Water would be conveyed from the reservoir to the river either through a constructed discharge pipeline or via the existing stream channel. Potential adverse geomorphic impacts to the Alder Creek channel that would result from construction and operation of a reservoir in Alder Creek Canyon could include channel degradation, likely in the form of channel incision, bed scour, or bank erosion. These impacts would be greater if releases to the existing downstream channel resulted in flow rates that are higher or are sustained for a longer period than existing flow rates. It is anticipated that releases to the creek would be controlled to minimize impacts on the hydrology downstream of the reservoir; however, it is important to note that many unknowns currently exist and the threshold at which potential impacts may occur cannot be determined without additional evaluation. This would be an item to address in subsequent design phases should the Alder Reservoir project proceed.

The primary unknown is the magnitude and fluctuation of releases to the creek from the reservoir. A detailed evaluation of reservoir operations is not part of the scope of this phase of study, but can be evaluated in more detail as part of future phases of study should the Alder Reservoir project proceed. For the sake of providing a preliminary evaluation of the geomorphic response, reservoir release is assumed to occur between May and October. In order to drain the 56,000-acre-foot reservoir during a 6-month period, an average flow rate of 154 cfs would need to be conveyed back to the Columbia River (Aspect and Anchor QEA, 2010), either through an appropriately sized discharge pipeline or through a combination of a pipeline and the existing stream channel. Actual reservoir operation will likely result in a variable release of water, with a higher peak discharge occurring during the months of July and August when the greatest demand for irrigation exists.

Potential downstream impacts to the channel are discussed with the assumption that the hydrology, including rates and fluctuation of flows, in the downstream channel would change due to reservoir construction and operation. However, as noted previously, the magnitude and timing of changes to downstream hydrology have not been defined and may be minimized by releasing most of the water through a constructed discharge pipeline. In addition, this assessment does not include a discussion of potential affects to surrounding landslide deposits along the canyon walls flanking the reservoir.

Comparison to Existing Hydrology

Downstream of Sally Spring, Alder Creek is a perennial stream, fed primarily by discharge from Sally Spring and by tributary flow from Sixprong Creek (also spring fed). Upstream of Sally Spring, flows in the creek are seasonal and primarily related to surface water runoff. Seepage from irrigation practices in the watershed may contribute a minor amount of surface water flow; however, based on field observation during late September 2011, it is unlikely that these practices contribute to the base flow of the creek.

The historical gage record available for USGS Gage #14034350 at Alder Creek is limited to the years between 1963 and 1968, and 1981 to 1982 (USGS, 2011). The gage is located near the mouth at an elevation of approximately 275 feet relative to the National Geodetic Vertical Datum of 1929 (NGVD29). A majority of the gage record was collected prior to the construction of the John Day Dam, which controls the elevation of the John Day Pool, in the 1970s. Therefore, the data does not capture the full impact of the backwater influence at the mouth of Alder Creek on the gage record.

Annual peak discharges reported at the Alder Creek gage range between approximately 17,600 cfs and 68 cfs. Peak flow rates occurred in December through early February. Because of the lack of available water surface elevation data at the Columbia River during this time, a correlation between the peak discharge values reported on the gage record and the influence of backwater from the Columbia River cannot be confirmed.

However, based on our observations and professional judgment, a discharge of 17,600 cfs seems unlikely for the system. Peak stream flows in the basin occur as a result of heavy precipitation, particularly rain-on-snow events that create excessive runoff.

For the time period when discharge of the reservoir to the channel downstream would likely occur (May through October), the mean monthly discharge reported for the gage record is between approximately 3.2 and 0.6 cfs (Table 3-1). There may be some differences in the current hydrology due to changes in surrounding irrigation practices, land use, or climate, but these months have significantly lower flows than the average discharge of 154 cfs that would be required to drain the proposed reservoir over a 6-month period. The *WRIA 31Watershed Management Plan* indicates that the existing gage record may overestimate long-term average flow conditions (WRIA 31 Planning Unit, 2008).

Table 3-1
Monthly Mean Discharge Reported at Alder Creek, cfs (USGS #14034350)

	May	Jun	Jul	Aug	Sep	Oct
1962	-	-	-	-	-	0.745
1963	2.14	1.06	1.09	0.826	0.800	0.887
1964	1.08	0.737	0.581	0.600	0.800	0.800
1965	2.60	1.49	0.806	1.95	1.08	0.916
1966	0.871	0.823	1.29	0.813	0.790	0.845
1967	1.33	0.843	0.558	0.513	0.673	0.732
1968	0.906	0.530	0.316	0.481	0.610	-
1980	3.22	1.78	0.729	0.602	0.751	0.971
1981	2.56	1.92	0.961	0.797	0.758	0.778
1982	2.55	1.52	1.07	0.385	0.511	1.09
Mean of Monthly Discharge	1.9	1.2	0.82	0.77	0.75	0.86

Potential Impacts to Channel Downstream of the Reservoir

Downstream of the proposed reservoir, Alder Creek contains locally steep boulder sections that appear to hold the channel grade in several places, and the channel planform is relatively confined by the surrounding alluvial terraces, colluvium, and bedrock. The grade is likely held in part by large beaver dams, particularly in Reaches 1 and 2 between Sally Spring and Sixprong Road. If reservoir operation resulted in sustained reservoir releases that were higher than existing flow rates in the channel, those releases could lead to local adjustment of the channel profile by mobilization of boulders and beaver dam material. This process may already take place when there are flood flows; however, current peak flows likely occur over a day or two and are not sustained over several weeks or months like a reservoir discharge would be.

If reservoir releases created flows that were higher than those currently conveyed through the downstream channel, the confined, steep channel would likely create deep, high-velocity hydraulic conditions in Reaches 1 through 3. These conditions could increase the potential for adverse scouring of the bed and for bank erosion. It appears that the pinch points in the canyon near Sally Spring and near the extent of backwater are likely canyon and channel grade controls, which would minimize the potential for a "catastrophic" level of channel profile adjustment.

3.2.2 Anticipated Issues for Permitting and Construction

Our preliminary review of the geomorphology in Alder Creek Canyon suggests that reservoir implementation could result in downstream impacts if reservoir releases to the downstream channel alter the timing and rate of flows in the channel. The extent of these impacts is uncertain because reservoir operations, including timing and rates of releases to the downstream channel, have not been defined. Should the Alder Reservoir project proceed, we expect that a more thorough evaluation of physical and biological impacts of reservoir operation would be completed as part of future phases of study prior to project permitting, design, and construction.

3.2.3 Potential Mitigation Opportunities

The potential for adverse impacts to the channel downstream of the reservoir will primarily depend on the magnitude of changes to the timing and rate of releases to the downstream channel. The following potential mitigation opportunities have been identified to address potential impacts to the channel downstream of the reservoir:

- Regulate reservoir releases to the channel to remain below an established critical discharge magnitude and frequency; and
- Convey discharge over the critical limit in a constructed discharge pipeline.

The most direct option to minimize impacts to the downstream channel is to regulate reservoir releases to the downstream channel to a flow rate that does not exceed a critical threshold of motion for bedload and bank sediments. Hydraulic analyses would be necessary to estimate the frequency and magnitude of flow that may be safely discharged without adverse effects. Calculating the threshold of motion of bedload sediment would require collection of bedload sediment samples, hydraulic modeling, and survey of the channel in areas of concern. Based on the size of sediments observed, volume of water to be stored, and release timing, this option may not be feasible.

Allowing for regulation of reservoir releases to the channel while still providing a way for the stored water to be released to the Columbia River would likely require construction of a discharge pipeline to convey a large portion of the water released from the reservoir. Installation of a conveyance pipeline in the lower 22,000 feet of Alder Creek Canyon was identified in the Pre-Feasibility Assessment (Aspect and Anchor QEA, 2010). Design of the discharge pipeline would likely require some additional analysis of canyon geology and stream conditions, particularly in narrow sections of the canyon.

3.2.4 Additional Considerations

Upstream of the proposed dam, Alder Creek is located within an alluvial canyon where the channel is relatively unconfined. Describing potential impacts to the channel within and immediately upstream of the reservoir footprint were not a part of the scope of this study, but it is important to note that geomorphic impacts in these areas are possible. This potential should be investigated further if the proposed Alder Reservoir moves forward.

Evaluation of sediment input to the reservoir was also not a part of this scope; however, the USGS gage record (#14034350) shows that suspended sediment was measured for a period of time and evaluation of that data may be prudent. Although the magnitude of present-day fine sediment loading is unclear, it is likely that the fines contributed to the channel are flushed out during seasonal high flows into the Columbia River (John Day Pool). The potential for settlement of fine sediments in the reservoir should be investigated as part of future study if the reservoir project moves forward.

Evaluation of sediment input should also be investigated further to determine if it is necessary to mitigate for impacts. Increased fines to the reservoir may be mitigated by building a low level sluice on the proposed dam to allow for flushing of sediment deposited in the reservoir. However, a low level sluice would likely only have localized sediment removal impact, primarily on sediment trapped behind the dam near the entrance to the sluiceway. Regulating the reservoir releases to maximize flushing of sediment downstream to the Columbia River could also help minimize sediment buildup in the reservoir over time.

3.3 Aquatic Habitat Assessment

An appraisal-level assessment of aquatic habitat was conducted in areas of Alder Creek Canyon that would be affected by the construction and operation of the proposed Alder Reservoir (area of impact). These areas included the proposed reservoir footprint and the stream channel from the proposed dam site downstream to the Columbia River (Figure 3-5). The assessment included a preliminary characterization of the area of impact using existing aerial photography, Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species (PHS) data, and field reconnaissance. Field reconnaissance was completed in late September 2011. During the field reconnaissance, stream flow characteristics, stream channel conditions, and aquatic habitat features were noted. The field reconnaissance did not include any wetland delineation, stream flow measurements, or other detailed field data collection. Photographs taken in Alder Creek Canyon during the field reconnaissance are included in Appendix A.

3.3.1 Current Understanding of Conditions

The conditions observed in Alder Creek Canyon were typical of conditions likely present in other tributaries within WRIA 31. In late September, stream flows were present only where sustained by groundwater input. Stream flows were absent in the canyon upstream of the proposed dam site and within the inundation footprint. The channel upstream of the proposed dam is characterized by a shallow and wide (approximately 15 to 20 feet) main channel with a boulder/cobble bed, and by multiple, adjacent, high-flow paths. Adjacent vegetation is sparse with occasional cottonwoods and native willow shrub species immediately adjacent to the channel, amidst shrub-steppe habitat-associated species. A recent high-flow event (likely spring 2011) was marked by a debris-line on the existing trees and shrubs. There was evidence of grazing within the corridor and little to no evidence of regeneration of trees and shrubs.

The primary source of surface flow in lower Alder Creek Canyon, Sally Spring, is located approximately 1.2 miles downstream of the proposed dam site (RM 3.0). Downstream of Sally Spring, Alder Creek is perennial. No flow measurements were made in Alder Creek as part of this study, but flows were estimated to be roughly 5 cfs based on visual observation during the field reconnaissance in late September 2011. That flow rate is greater than the typical mean daily flow rate recorded for the same time of year at the former USGS gage near the mouth of Alder Creek for the 1960s period of record shown in Table 3-1. There was no obvious indication of why the observed flow rate might be higher than the mean daily flow at the USGS gage at that time of year during the period of record. There could potentially be more flow due to increased irrigation return flow or because flows were observed at the end of a water year that was wetter and cooler than normal. Flow measurements would be needed to confirm flow rates throughout the year. The observed channel was typically approximately 10 to 15 feet wide and 3 to 5 inches deep. Measured water temperatures were consistently in the range of 12 to 14 degrees Celsius (°C) downstream of Sally Spring.

At the confluence of Sixprong Creek and Alder Creek (RM 2.7), the Sixprong Creek channel is a relatively straight, gravel-bed channel approximately 6 to 10 inches wide and 3 inches deep, cutting through a mostly grassy, very narrow floodplain. Inflow from Sixprong Creek was visually estimated to be approximately 2 cfs. The water temperature was measured at 14°C.

Between Sixprong Creek and the Sixprong Creek Road Bridge, Alder Creek was very accessible. There was evidence of beaver activity, including a number of well-established beaver ponds, and floating, beaver-chewed branches and chewed tree stumps. Canopy closure was estimated as close to 80 to 90 percent in the reaches with wider riparian buffers, the understory was healthy, and re-growth was occurring. Observed tree species were exclusively Alder (*Alnus* sp.) upstream of the Sixprong Creek Bridge, mixed with some locust just upstream of the backwatered reach. Understory was mostly shrubby alder re-growth, with some sumac (*Rhus* sp.), rose (*Rosa* species), and currant (*Ribes* species) along the edges of some riparian areas. Observed wetland plant species included forb species (i.e., mint, nettle), cattail, bullrush, sedge (*Carex* sp.), rushes (*Juncus* sp.), and emergent vegetation (i.e., duckweed). Periphyton growth was prominent in the stream channel. Non-native thistle species were prevalent throughout the entire riparian area, sometimes in dense thickets along the beaver-ponded reaches. There was evidence of grazing throughout, although the disturbance was not excessive.

The wider riparian area in the reach upstream of Sixprong Creek allowed for multiple channels with a well-developed overstory. Woody material was plentiful within the stream channels, and boulders formed pools and provided instream cover. Fish species observed were mostly cyprinids, with some sculpin (*Cottus* sp.) and juvenile suckers (*Catostomus* sp.). Crayfish were numerous and caddis fly larvae cases and adult dragonfly were observed.

Downstream of the Sixprong Creek Bridge, Alder Creek was mostly inaccessible but could be viewed from high vantage points along Alderdale Road, which parallels the valley-bottom channel. At one accessible location approximately 1/2 mile upstream of the backwatered stream reach near the mouth of Alder Creek, the channel was split by a narrow terrace, with one dry channel and one channel with approximately 5 cfs of flowing water (estimated based on visual observation). The other accessible stream location was within the Columbia River backwater-affected stream reach. This reach extends approximately 1/2 mile upstream from the confluence with the Columbia River (to RM 0.5). The stream through this reach resembles a lentic system, widening to fill the widening valley bottom. Wide, dense stands of bulrush and shrub species line the right stream bank; the left bank is mostly steep and supported shrub-steppe plant species. Where the channel narrows and the gradient increases upstream of the backwatered section, the riparian vegetation reverts to mature Alder trees, with a dense shrub/grass-forb understory and a pool/riffle/run, boulder/cobble bed.

3.3.2 Anticipated Issues for Permitting and Construction

Available information and observations made during the field reconnaissance were used to evaluate potential impacts to aquatic habitat, instream flow conditions, and wetland characteristics that might result from construction and operation of the proposed Alder Reservoir. Successful permitting and implementation of the project will likely require that the project avoid or minimize and mitigate unavoidable impacts. A few key issues and requirements that will likely need to be addressed have been identified.

The lower reach of Alder Creek from the mouth upstream to Sally Spring, including Sixprong Creek, is designated critical habitat for Endangered Species Act (ESA)-listed Mid-Columbia Summer Steelhead (Federal Register 50 CFR Part 226). Potential spawning and rearing habitat has been identified in Alder Creek upstream to the confluence with Sixprong Creek. Generally, spawning may occur anywhere in the identified areas where suitable substrate material is found. Rearing may be similarly widespread during most of the year, but may be restricted to spring-fed or groundwater upwelling areas during the summer and early fall (Washington State Conservation Commission [WCC] 2000). WDFW (Dugger, 2000) reported potential spawning and rearing habitat in Alder Creek from the confluence with the Columbia River upstream to Sixprong Creek. The Yakama Nation (NMFS, 2009) reported observing steelhead adults in the lower 1.5 miles of Alder Creek. Obtaining a determination of No Jeopardy or No Adverse Modification to critical habitat would be very challenging and time consuming. To obtain an understanding of potential project impacts to ESA-listed steelhead, a fish survey would be needed to document the presence, absence, and extent of use by steelhead. A fish survey protocol that is supported by the local fisheries management agencies would need to be developed and implemented, preferably including documentation of all fish species detected during the survey.

Impacts of the proposed project’s construction and operation on the hydrology of Sally Spring would need to be determined. There is some contribution of surface flow from Sixprong Creek, which is also spring-fed; however, the major source of surface flows in Alder Creek downstream of Sally Spring appears to be Sally Spring itself. In general, the overall potential impact of the project on surface flows and spring activity in Alder Creek from Sally Spring downstream to the mouth would need to be determined. If changes to hydrology are identified, related impacts on habitat would also need to be described. A proposal to mitigate for impacts would need to be developed.

A wetland delineation would need to be conducted and a mitigation plan developed to quantify the amount and quality of wetland habitat in Alder Creek potentially impacted by the construction and operation of the proposed Alder Reservoir. Although no wetland habitats were evident or observed at the proposed dam site or upstream of the site, operation of the storage facility could alter the function of wetlands downstream of the dam site. Given the topography of Alder Canyon downstream of the proposed dam site, there are likely opportunities for enhancing wetlands in lower Alder Creek. In particular, in the inundated reach of lower Alder Creek, wetland functions could be improved by controlling non-native plant species and planting native trees and shrubs.

3.3.3 Potential Mitigation Opportunities

To address unavoidable impacts to aquatic habitats from project construction and operation, potential mitigation opportunities have been identified.

With the construction of Alder Reservoir, stored water could be made available to enhance the perennial flows in Alder Creek downstream of the reservoir. This source of water could be used to mitigate for potential disruption to instream flow contributions from spring-fed groundwater recharge to Alder Creek. It is assumed that releases from the reservoir would be partially conveyed through a pipeline so that flows downstream of the reservoir would not negatively impact the channel bed or banks, or instream or riparian habitat, consistent with the channel’s geomorphic conditions (see section 3.2.3).

Because of the apparent fatal flaws that were identified relative to landslide conditions in Alder Canyon, temperature modeling of releases from the proposed Alder Reservoir was not completed as part of this study. The reservoir would likely exhibit a measure of thermal stratification during the summer, with cooler water at the bottom and warmer water at the top. Water would likely be drawn from low in the reservoir’s water column, supplementing downstream flows with cooler water during the summer. The cooler water could be used to mitigate for any loss of coldwater inputs from existing spring-fed groundwater inputs into Alder Creek downstream of the reservoir.

With the potential for increased flow downstream of the reservoir, habitat improvement actions could be designed and implemented in the stream channel and adjacent floodplain/riparian areas to enhance steelhead spawning and rearing conditions in the Alder Creek drainage. Habitat improvement actions could also be designed and implemented in existing side channels of the Columbia River near the confluence of Alder Creek, to enhance available off-channel juvenile salmonid rearing habitat in this reach of the Columbia River. With the creation of the reservoir, riparian and wetland habitat could be created along the reservoir shorelines as mitigation for wetland and stream habitat impacted by construction and operation of the storage reservoir.

3.4 Terrestrial Habitat Assessment

An appraisal-level assessment of terrestrial habitat and wildlife species was conducted in areas of Alder Creek Canyon that would be affected by the construction and operation of proposed Alder Reservoir project (area of impact). These areas included the proposed reservoir footprint, potential pipeline construction alignment, and the stream channel from the proposed dam site downstream to the Columbia River (Figure 3-5). The assessment included a preliminary characterization of the area of impact using existing aerial photography, WDFW PHS data, and field reconnaissance. Field reconnaissance was completed in late September 2011. During the field reconnaissance, existing terrestrial habitat conditions were observed, noting critical habitats such as talus slopes, riparian habitat, and native shrub-steppe habitat. The presence of native wildlife was noted when observed. The field reconnaissance did not include any detailed field investigations or measurements that would be needed to more clearly delineate or classify habitat conditions. Photographs taken in Alder Creek Canyon during the field reconnaissance are included in Appendix A.

3.4.1 Current Understanding of Conditions

Terrestrial habitat in the Alder Creek drainage is dominated by shrub-steppe habitat with a well-developed riparian corridor downstream of Sally Spring and very limited riparian habitat upstream of Sally Spring. Alder Creek Canyon upstream of Sally Spring is generally relatively broad with gently sloping hills, bisected by dry, narrow cuts, rising up to the surrounding plateau. The observed shrub-steppe habitat was in good condition, with a grass understory dominated by non-native cheat grass (*Bromus tectorum*). Riparian habitat was infrequent and located immediately adjacent to or within the dry streambed or one of its floodways. Where riparian habitat did occur, it consisted primarily of very sparse collections of native willow, with a few mature, native cottonwood trees (*Populus trichocarpa*). There was no regrowth associated with the live cottonwood trees noted, but there were scattered standing dead trunks of cottonwood saplings adjacent to the dry watercourse in the reach immediately downstream of Cow Camp. Grazing impacts may have contributed to the death of young trees and the lack of regrowth observed in the arid environment of upper Alder Creek.

Downstream of Sally Spring, the canyon narrows with the hillslopes and surrounding uplands still dominated by shrub-steppe habitat; however, the observed riparian corridor is well developed and extends from the stream channel to the toe of adjacent slopes (visually estimated 50 to 500 feet in width). Alder trees exclusively form the overstory in the riparian corridor, providing good canopy cover. Understory shrubs include sumac, currant, and rose. There was evidence of grazing within the riparian corridor; however, the effects appeared to be limited. Shrub-steppe habitat continued to dominate the hillslopes and uplands where the backwater effect of the Columbia River began to influence the stream corridor. The riparian corridor adjacent to the ponded reach of Alder Creek appeared to be limited by the high water table. Documented wildlife species included beaver, muskrat, flickers, great blue heron, flycatchers, coyote, deer, owl, magpies, and turkey.

3.4.2 Anticipated Issues for Permitting and Construction

Available information and observations made during the field reconnaissance were used to evaluate potential impacts to terrestrial habitat that might result from construction and operation of the proposed Alder Reservoir. Successful permitting and implementation of the project will likely require that the project avoid or minimize and mitigate unavoidable impacts. A few key issues and requirements that will likely need to be addressed have been identified.

The primary potential impacts related to terrestrial habitat include loss of shrub steppe habitat within the footprint of the reservoir and potential changes to the riparian area downstream of the dam as a result of reservoir construction and operation. An estimate of the quantity and quality of shrub-steppe habitat within the footprint of the inundation area and within any planned pipeline corridor would need to be prepared and a mitigation plan would need to be developed. Shrub-steppe habitat is listed as a Priority Habitat under the PHS Program. A survey documenting baseline conditions of the extent and composition of riparian habitat downstream of the proposed dam site might also be required. In addition, if changes in hydrology downstream of the dam are identified, related impacts on terrestrial habitat would also need to be described and a proposal to mitigate for any impacts would need to be developed.

3.4.3 Potential Mitigation Opportunities

To address unavoidable impacts to terrestrial habitats from project construction and operation, potential mitigation opportunities have been identified.

Generally, terrestrial habitat conditions in the Alder Creek corridor are functioning well, so there are limited opportunities to mitigate for impacts to shrub-steppe habitat that may be negatively affected by the construction and operation of the proposed project. Mitigation opportunities could include limiting or excluding grazing from riparian corridors. However, enhancement opportunities in the uplands are dependent on landowner support. Upland enhancement opportunities are often not consistent with agricultural objectives, so getting support from landowners can be challenging. Excluding grazing from riparian areas requires fencing and is maintenance-intensive. In arid landscapes like the Alder Creek drainage, riparian areas often offer the only access to shaded cover available, making it very difficult to exclude grazing animals. With the creation of a year-round, open body of water, there would be opportunities to create riparian habitat in upper Alder Creek Canyon to benefit upland game birds, deer, and non-game wildlife.

The creation of this type of valuable habitat in an otherwise arid landscape could be used as in-kind mitigation for the limited impacts to riparian habitat that may occur within the inundation footprint, but could also be proposed as out-of-kind mitigation for impacts to shrub-steppe habitat. Enhancement to the riparian corridor downstream of the proposed dam site could be implemented to improve habitat conditions for terrestrial wildlife in the drainage as additional out-of-kind mitigation, although these opportunities are limited by the already good condition of the existing riparian habitat.

3.5 Cultural Resources Assessment

3.5.1 Background and Regulatory Context

For the purpose of completing a preliminary cultural resources review of the proposed project area, the proposed Alder Reservoir was located on the Alderdale USGS 7.5-foot Quadrangle, in the following sections:

- Township 4 North, Range 22 East: Section 1
- Township 4 North, Range 23 East: Sections 3, 4, 5, 6, 7, 9, 10, 15 and 16
- Township 5 North, Range 23 East: Sections 19, 20, 21, 22, 27, 28, 29, 31, 32, 33, and 34
- Township 5 North, Range 22 East: Sections 13 and 24

The project area is also illustrated on Figures 1-1 and 3-1.

The project will require permits from the U.S. Army Corps of Engineers (Corps), and other federal agencies may also be involved as plans develop. The Corps and any other federal agencies must comply with Section 106 of the National Historic Preservation Act, which requires agencies to take into account the effects of their undertakings on historic properties. According to the Section 106 implementing regulations at 36 CFR 800, an historic site or property may include a prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places (NRHP). State laws and regulations also require consideration of cultural resources, including the State Environmental Policy Act (SEPA) and Revised Code of Washington 27.53 Archaeological Sites and Resources.

To comply with Section 106 and applicable state laws, the federal agencies or their designees should take the following steps:

1. Define the project's Area of Potential Effects (APE), which is "the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties" (36 CFR 800.16[d]).
2. Initiate consultation with interested and affected Indian tribes, Department of Archaeology and Historic Preservation (DAHP), and any other interested parties (36 CFR 800.3).
3. Identify historic properties (including Traditional Cultural Properties [TCPs]) within the APE, and determine whether they are NRHP-eligible (36 CFR 800.4).
4. Apply the criteria of adverse effect to determine whether the project will have adverse effects on NRHP-eligible historic properties within the APE (36 CFR 800.5).
5. If there will be adverse effects, develop mitigation measures in consultation with DAHP, tribes, and other interested parties, and describe those measures in a Memorandum of Agreement or Programmatic Agreement (36 CFR 800.6).

Because the APE for the project will be large and is likely to contain a number of pre-contact and historic sites, it may be appropriate to develop historic context statements with input from consulting parties prior to fieldwork. This will streamline determinations of NRHP eligibility and reduce the opportunity for conflicts about site significance.

This section of the appraisal assessment will assist the WRIA 31 Planning and Advisory Committee in preparing to comply with federal and state laws and regulations by describing previous archaeological research in the area, locating recorded resources that may be affected by the project, and making recommendations for further research.

3.5.2 Environmental and Cultural Context

The following provides general background on the environment, archeology, ethnography, and history of the Horse Heaven area. This information provides context for cultural resources assessments for both the proposed Alder Reservoir and Switzler Reservoir projects.

Environment

The Horse Heaven area is in the Columbia Basin physiographic province, which is characterized by Plio-Pleistocene glacially derived sediments overlying the Columbia River Basalt formation (Franklin and Dyrness, 1973; Lasmanis, 1991).

The area forms the southern part of the Channeled Scablands of eastern Washington, a region bounded by the Columbia, Snake, and Spokane rivers (Weis and Newman, 1976). The scablands formed when glacial Lake Missoula broke through its ice dam repeatedly between 13,000 and 20,000 years ago, causing catastrophic floods that carved deep channels into sediments and bedrock (Alt, 2001; Weis and Newman, 1976).

Numerous dams were constructed on the Columbia River in the twentieth century. The McNary Dam, completed in 1954, is approximately 9 miles downstream of the Switzler Canyon area and approximately 31 miles upstream of the Alder Creek area. The reservoir behind the dam, Lake Wallula (also commonly known as the McNary Pool) extends upstream of the Kennewick, Washington, area. The John Day Dam, completed in 1971, is approximately 40 miles downstream of the Alder Creek area. The reservoir behind the dam, Lake Umatilla (also commonly known as the John Day Pool) extends to the McNary Dam. Both reservoirs flooded the former Columbia River shoreline in their respective reaches.

The climate is arid, with an average of 8.9 inches of annual precipitation; January's average low temperature is 26.2 degrees Fahrenheit (°F) and July's average high temperature is 88.1°F (Daly, 2011). The intermittent and permanent streams in WRIA 31 drain directly to the Columbia River. Alder Creek and Glade Creek are the most prominent drainages in the Horse Heaven area. Soils in the area are typically formed in shallow to very deep loess, alluvium, or volcanic sediments over bedrock (Rasmussen, 1971).

The project area is in the shrub-steppe vegetation zone, and vegetation is typically dominated by sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), Idaho fescue (*Festuca idahoensis*), and bluebunch wheatgrass (*Agropyron spicatum*; Franklin and Dyrness, 1973), which provide high-quality grazing (Stern, 1998).

Prior to the introduction of the horse, grazing mammals in the area included deer (*Odocoileus virginianus, Odocoileus hemionus*, and *Odocoileus microtus*), wapiti/elk (*Cervus canadensis* [sometimes regarded as conspecific with *C. elaphus*]), Pronghorn antelope (*Antilocapra americana*), and mountain goat (*Oreamnos americanus*; Burke Museum, 2011). Small mammals include coyote (*Canis latrans*), jackrabbit (*Lepus californicus* and *Lepus townsendii*), and various voles and ground squirrels (Burke Museum, 2011). Salmon and steelhead are available in the Columbia River and tributaries seasonally, and white sturgeon, lampreys, suckers, and trout are present year-round.

Archaeology

The Horse Heaven area is in the Southern Plateau, which is part of the larger Columbia Plateau culture area. The Southern Plateau stretches from southern Okanogan County in the north to the northern border of the Great Basin to the south. The archaeology of the Horse Heaven area is not well known, but is likely similar to elsewhere in the Southern Plateau.

At the end of the Pleistocene, hunters of large mammals fanned out across North America. This period is known in the Columbia Plateau as Paleoindian (Ames and Maschner, 1999), and in the southern Plateau as Period Ia (Ames et al., 1998). In the Columbia Plateau as a whole, Chatters and Pokotylo (1998) included these early mobile foragers in the Early Period from approximately 11,000 to 8,000 years ago. The earliest Paleoindian sites recorded in the Columbia Plateau are attributed to the Clovis culture, including the Ritchey-Roberts Clovis cache in East Wenatchee, which dates to 12,250 BP (Mehringer and Foit, 1990). There are no recorded Clovis sites in the Horse Heaven area, and Clovis sites are rare across the region.

After the brief but widespread Clovis occupation, a “broad-spectrum” hunter-gatherer culture developed in the Columbia Plateau region and persisted until the middle Holocene, around 5,300 years ago. This culture spans the latter part of the Early Period and the Early Middle Period in the Columbia Plateau sequence (Chatters and Pokotylo, 1998), and the Period Ib in the Southern Plateau sequence (Ames et al., 1998).

A shift toward more permanent settlement began around 6,000 years ago. Known as the Late Middle Period in the Columbia Plateau and the Period II in the Southern Plateau, this period lasted until the beginning of the early Holocene around 3,000 years ago (Chatters and Pokotylo, 1998; Ames et al., 1998). In general, Period II tool assemblages are characterized by the addition of groundstone and bone/antler tools to the existing flaked stone technology.

Late Holocene cultures in the Columbia Plateau region exhibit a “shift in adaptations…to storage-dependent collector strategies” (Chatters and Pokotylo, 1998:76), which are characterized by intensive salmon fishing and associated storage features, social inequality, large permanent winter villages, and diverse tool assemblages. Labeled the Late Period, this shift begins around 3,000 years ago and persists until historic contact (Chatters and Pokotylo, 1998). In the southern Plateau, the contemporaneous Period III also includes evidence of intensive camas processing and fiber and wood artifacts preserved in the relatively dry climate (Ames et al., 1998). The late Holocene archaeological cultures correlate with historic ethnographic descriptions.

Ethnography

The Horse Heaven area is in the traditional territory of several Native American tribes. Early ethnographic research described the tribes in the area as the Yakima, Tenino, Wanapum, Walla Walla, and Umatilla (Kroeber, 1939). More recently, Walker (1998) described occupation by the Yakima “and neighboring groups” in the northern half of the Horse Heaven, and the Cayuse, Umatilla, and Walla Walla in the southern half. Stern (1998) assigns the entire Horse Heaven to the Umatilla. Just 75 miles west of the Horse Heaven area, in the vicinity of The Dalles, Oregon, “the Northwest Coast and Plains cultures met directly” (Stern, 1998:396). Given the area’s use by various tribes, intertribal relationships were very important in the region (CTUIR, 2011).

Territorial boundaries were apparently somewhat fluid, especially during the disruptions caused by Euro-American contact (Stern, 1998), but the tribes in the area can be generally described as Sahaptin-speaking Plateau groups with broadly similar lifeways (Walker, 1998). Traditional Plateau cultures were based on a seasonal round that took advantage of fish runs, game, and root resources, as well as trade, kinship ties, and intermarriage among groups (Walker, 1998). Prior to historic resettlement, permanent winter villages anchored the seasonal round (Boyd and Hajda, 1987). Villages consisted of large mat lodges, each housing an extended family, and occasionally also smaller conical structures (Stern, 1998; Schuster, 1998). Villages were the basic political unit (Schuster, 1998).

Fishing activities revolved around an early salmon run in March, and a second, larger run in June (Schuster, 1998). Fishing technology included the portable (toggling harpoons, leisters, hook-and-line, and nets) and the non-portable (traps, weirs, and platforms at permanent fishing stations) (Schuster, 1998; CTUIR, 2011). Gathering activities took place throughout the year. Fish, roots, and berries were processed, dried, and stored (CTUIR, 2011). Although salmon were a key staple, plant foods also made up a significant portion of the diet (Hunn, 1981). Religious life involved adherence to both the Guardian-Spirit complex, which included the sweatlodge and curative “sings”; and the Washat religion, which was based on ceremonies held in the longhouse and included first food feasts in the spring celebrating the return of the salmon and newly sprouting plants (Schuster, 1998; CTUIR, 2011).

History

By the time of the first sustained contact between the tribes of the Horse Heaven area and Euro-American settlers in the mid-1800s, tribal life had already been significantly impacted. Introduced diseases decimated the population (Vibert, 1997:50) while the introduction of the horse altered social and economic activities (CTUIR, 2011)

The earliest recorded Euro-American exploration of the Columbia River was in 1792 (Hayes, 1999), but the Horse Heaven area had no recorded contact until the Lewis and Clark Expedition from 1805 to 1806 (Clark et al., 1814). Exploration and settlement of the entire Columbia River area was slow until the 1840s when Americans were attempting to wrest control from the British (Mackie, 1997). The Oregon Treaty of 1846 awarded the Oregon Territory to the United States, but the arid Horse Heaven area was still sparsely populated (Wells, 2000).

In 1853, Washington became a territory separate from Oregon, and by the next year Governors of both the territories began pursuing treaties that relegated tribes to reservations (Wilma, 2003; CTUIR, 2011). Fourteen tribes and bands signed the Treaty of 1855 that established the Yakama Indian Reservation, north of the Horse Heaven area (YNM, 2011). The Walla Walla, Cayuse, and Umatilla Tribes signed the Treaty of June 9, 1855 that established the Umatilla Indian Reservation (CTUIR, 2011). The tribal people of the Horse Heaven area are now members of the Confederated Bands and Tribes of the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation, and some individuals may be members of other tribes.

The Horse Heaven area was named by Euro-American settlers for the native grasses which provided excellent grazing (Kirk and Alexander, 1990:138), and the first intensive use of the area was by ranchers in the 1870s (Gibson, 2004). The first detailed maps were made by the General Land Office between 1858 and 1867 (Figure 3-6). The maps do not show cultural features in the project area. The construction of railroads in the 1880s and irrigation infrastructure in the 1890s led to a shift from ranching to agriculture (Wells, 2000), though the Horse Heaven remained sparsely populated.

Today the only Census Designated Places in the Horse Heaven are the small towns of Roosevelt (population in 2000 was 79, located approximately 12 miles west-southwest of the proposed Alder Reservoir) and Bickleton (population in 2000 was 113, located approximately 20 miles northwest of the proposed Alder Reservoir). The larger Tri-cities area is north and northeast of the Horse Heaven Hills, approximately 10 miles north of the proposed Switzler Reservoir. The area remains primarily agricultural.

3.5.3 Previous Research

Archaeological Surveys

Relatively little archaeological research has been conducted in the Horse Heaven area. Most surveys have been Section 106 compliance reviews of either linear projects (such as roads and pipelines) or small projects (such as irrigation equipment installation). The most comprehensive research projects in the area have been conducted along the shores of Lake Wallula and Lake Umatilla (Doucker, 1948; Shiner, 1950, 1955; Minor, 1991; Dickson, 1999). The surveys conducted in the 1940s and 1950s may have traversed the current project area, but researchers did not report exactly where reconnaissance occurred; whether the project area was examined during those surveys is unknown.

Only one archaeological survey has been conducted within the footprint of the proposed Alder Reservoir. That survey was a pedestrian reconnaissance of a paving and realignment project on Alderdale Road; no archaeological sites were located (Regan, 2000). Three surveys have been conducted within approximately 1 mile of the footprint of the proposed Alder Reservoir. Two recorded no archaeological materials, and one recorded an historic refuse deposit (see Table 3-2).

Table 3-2
Previous Archaeological Surveys – Proposed Alder Reservoir Area

Author and Date	Title	Survey Methods	Findings	Distance from Proposed Project
Regan 2000	A Cultural Resources Survey for Improvements to Alderdale Road, SR 14 to Yakima County Line, Klickitat County, Washington	Pedestrian reconnaissance	No archaeological materials were located	Within the footprint of the proposed Alder Reservoir
Jones & Stokes 2002	BPA McNary-JohnDay Transmission Line Project Archaeological Survey	Pedestrian reconnaissance and subsurface testing	In the portion of the surveyed area that is near the proposed Alder reservoir, previously-recorded precontact site 45KL265 was visited, and new historic site 45KL862 was recorded	Approximately ½ mile south of proposed Alder Reservoir
Ragsdale et al. 2007	Archaeological and Historical Investigation for the Plymouth to Goldendale Pigging Project	Pedestrian reconnaissance and subsurface testing	No archaeological materials were located	Approximately 1 mile west of the proposed Alder Reservoir
Woody 2008	NRCS McBride Hereford Ranches Inc, EQIP 2008 Site Identification Survey in Klickitat County, Washington	Pedestrian reconnaissance	No archaeological materials were located	Approximately 1 mile northwest of the proposed Alder Reservoir

Recorded Archaeological Sites

There are no recorded archaeological sites within the footprint of the proposed Alder Creek Reservoir, or within one mile of the potential ASR well field near Alderdale Road (Figure 3-7). Within a mile of the proposed Alder Creek Reservoir, two sites have been recorded. Site 45KL265 is a precontact lithic scatter recorded in 1980 (Wiggin et al. 1980) and revisited in 2001 (Jones & Stokes, 2002). The site is reported to be in “stable yet poor” condition, threatened by grazing, off-roading, and artifact collecting (Jones & Stokes, 2002). Site 45KL862 is an historic refuse deposit, apparently related to a single dumping episode in the early twentieth century (Cooper, 2002). A third site, the former Alderdale townsite (45KL328), is just over a mile south of the proposed Alder reservoir. The townsite was partially submerged by Lake Umatilla, and the remaining upland portion was apparently mostly destroyed by “relocation of the railroad and highway” (Minor, 1991:25). None of these sites have been evaluated for NRHP eligibility.

Although there are no recorded sites within the reservoir and potential ASR well field footprints, almost none of the area has been surveyed. Archaeological research in the area has focused on the banks of the Columbia River, but upland areas in Klickitat, Yakima, and Benton counties also host a variety of precontact and historic site types, including:

- Historic structures, equipment, homesteads, and refuse deposits related to early ranching and agriculture;
- Precontact and historic cairns (including burial cairns);
- Lithic scatters, isolates, and quarries;

- Processing sites; and
- Cave sites.

Similar sites are likely to be present within the project area as well.

Traditional Cultural Properties

There are no TCPs in the project area that are recorded at the DAHP. Tribes should be consulted as the project develops to determine whether any TCPs are present in the area that may be affected by the proposed Alder Creek Reservoir project.

Built Environment

There are no recorded NHRP-eligible or listed structures, bridges, or buildings in the project area.

3.5.4 Anticipated Issues for Permitting and Construction

The project will require a complete inventory of historic properties that may be affected by construction of the proposed reservoir and related facilities. Inventory should include both archaeological survey and a review of the built environment (houses, outbuildings, bridges, irrigation structures, and equipment that will be older than 50 years at the estimated time of project construction).

3.5.5 Potential Mitigation Opportunities

If NRHP-eligible historic properties will be adversely affected by the project, mitigation will be determined by the federal agencies and DAHP, in consultation with tribes and other interested parties.

3.6 Conclusion for Alder Reservoir

Based on the information described above for each technical discipline, we conclude that Alder Reservoir is fatally flawed because of potential landslide hazards. There are numerous large-scale existing landslides identified within the reservoir area, and there is a reasonable likelihood for existing landslides to re-activate, or new landslides to be triggered, with repeated cycles of saturation during proposed reservoir operations. The landslide hazard poses a reasonable risk for significant damage to the reservoir and, especially if new landslides are triggered, to adjacent property. Given the magnitude of the existing landslides, there are not cost-effective methods for reducing the impacts.

We recommend not proceeding with Phase 2 engineering for Alder Reservoir

4 Fatal Flaw Assessment for Switzler Reservoir

This section presents our assessment of potential fatal flaws for the proposed Switzler Reservoir, culminating in a recommendation for whether it should proceed into the Phase 2 engineering assessment. The fatal flaw assessment is based on the information collected in the course of this Phase 1 work, subject to the available budget and schedule. Future collection of additional information could change the assessment and conclusions regarding fatal flaws.

The subsequent subsections address the following technical disciplines relevant to permitting, constructing, and operating the proposed Switzler Reservoir:

4.1 Geologic Hazards and Slope Stability

4.2 Channel Geomorphology

4.3 Aquatic Habitat

4.4 Terrestrial Habitat

4.5 Cultural Resources

4.6 Water Quality

Based on the collective available information generated in Sections 4.1 through 4.6, Section 4.7 presents the conclusions and recommendation regarding Switzler Reservoir.

4.1 Geologic Hazard and Slope Stability

A preliminary analysis of geologic hazards including fault rupture hazards and reservoir slope stability was conducted for the proposed Switzler Reservoir site. The analysis consisted of compilation and review of geologic information on the site, conducting a geologic site reconnaissance to review existing conditions including existing slope stability, and a fatal-flaw-level assessment of seismicity-related hazards including fault rupture, slope stability hazards, and assessment of geological impacts to the reservoir and surrounding area that could occur through operation of the reservoir. The site geologic reconnaissance was conducted on September 28 and 30, 2011, by a licensed engineering geologist from Aspect Consulting.

Results of the analysis indicate that there are no known fault rupture hazards or other seismic hazards that lie within the dam or reservoir footprint that cannot be mitigated during design and construction. Two deep seated old landslides have been identified at the site. In addition, there are two areas where erosional undercutting of steep sand and silt loess and colluvium-covered canyon slopes have triggered shallow slope failures. Results of preliminary numerical slope stability analyses suggest that the surficial silty and sandy loess/colluvium layer is unstable during immersion and during seismic shaking. The deeper sandy to gravelly glacial flood deposits is more stable, but may experience some failures during immersion and/or seismic shaking. Basalt bedrock appears generally stable under these conditions.

During reservoir operations, there is a high risk of activation of shallow surficial landslides within the reservoir area and slopes that could extend above the area reservoir. Where agricultural plots extend to within several tens of feet of the rim of the canyon, there is some risk of adverse impacts on the operations. In our opinion, there is small likelihood that these shallow landsides would impact land and agricultural operations more than several tens of feet from the canyon rim.

Additional field and design studies would be necessary to assess the stability of the suspected older deep-seated landslides, and their potential to re-activate during reservoir filling and operations, should Switzler Reservoir proceed into later design phases. If they were found to be unstable, design and construction would need to accommodate the risk of reactivation and movement of the deep seated landslides within the reservoir area. At this time, no cost effective technologies have been identified for reducing the probability of reactivating old deep-seated landslides or triggering new shallow landslides. Mitigation would consist of some combination of designing the reservoir facilities and operations to accommodate the hazards, establishment of high risk setback areas, or compensation for loss of use of property in the event that landslides damage occurs.

Due to the relatively minor part of the reservoir that appears to contain old deep-seated landslide deposits, and the shallow nature of the predicted surficial slides, we do not consider slope stability to be a fatal flaw for the Switzler Reservoir site. In our opinion based on our current understanding, slope hazards can be mitigated during design, construction, and reservoir operations.

A summary description of existing site conditions and potential impacts and mitigation is presented below.

4.1.1 Current Understanding of Conditions

The Switzler Reservoir site is about 16 miles south of Kennewick, and 11 miles east of Plymouth and Umatilla (Figure 1-1). Switzler Canyon lies within the Columbia Basin physiographic province, an area of broad valleys with gently dipping surfaces separated by moderately to steeply dipping linear ridges. It occupies the gently dipping southwest facing flank of the Horse Heaven Hills, a broad east-west to northwest trending ridge and series of anticlines that that rises about 1,500 feet above the surrounding valley bottoms. The Switzler Canyon drainage flows southwest from the upland of the Horse Heaven Hills and discharges to Lake Wallula, the reservoir (pool) of McNary Dam on the Columbia River.

The Switzler Canyon drainage is about 300 to 500 feet deep and 2,000 feet wide within the proposed reservoir area. The canyon walls range from cliffy and benched, to uniform steep surfaces that dip up to about 28 degrees or 55 percent. Existing topography is presented on Figure 4-1.

The proposed Switzler Reservoir configuration includes an earth fill dam located about a mile upstream of the confluence of Switzler Canyon and Lake Wallula. The base of the dam would lie at about elevation 450 feet, and crest at about elevation 790 feet creating a reservoir about 330 feet deep at the dam. About ¾ mile upstream of the dam, the reservoir would fork and extend about a mile into an un-named tributary herein called the “west fork” of Switzler Canyon. The longer “east fork” would extend about 2¼ miles farther up the main drainage of Switzler Canyon for a total reservoir length of about 3 miles (Figure 4-1). Operational water levels would vary from about elevation 780 feet to 450 feet, resulting in reservoir drawdowns of about 330 feet.

Regional Geology

The nature of the canyon at the reservoir and dam site, and the overall stability of the site are functions of site geology, climate, and surface water and groundwater. Bedrock within the Columbia Basin is composed of many stacked basalt flows, each tens to hundreds of feet thick. The basalt flows are separated by rubbly to clayey flow contacts and locally by sedimentary interbeds that if present may be many tens of feet thick. These Miocene-age 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. Figure 4-2 depicts the surface geology in the Switzler Reservoir area.

Tectonics and Geologic Structures

The entire Columbia Basin has been subjected to tectonic compression and rotation at least since the time of the placement of the basalt flows between about 17 and 6 million years ago, and the compression and rotation continue today. As the regionally extensive flows of basalt that had been were being erupted and were cooling, they were also being folded by these compressive stresses, creating what is called the Yakima Fold and Thrust Belt. The Yakima Fold and Thrust Belt is a series of steep, asymmetric, anticlinal folds and associated thrust faults separated by broad, gently dipping synclines. Typically the limbs of the synclines dip a few to about 10 degrees while the limbs of the anticlines are more steeply dipping, with sections that may be vertical or even over-turned. The site lies within a tectonically complex and poorly understood area where a number of east-west trending anticlines including the Columbia Hills and the Horse Heaven Hills bend and merge into the northwest trending Olympic-Wallowa Lineament (OWL). The OWL a topographic and tectonic feature that extends from western Washington to eastern Oregon, locally includes the series anticlinal ridges and hills of Rattlesnake Ridge. The Switzler Reservoir site lies about three miles south of the Columbia Hills anticline, and about seven miles southwest of the Rattlesnake Ridge anticline (outside the map view shown on Figure 4-2).

Fault and Seismicity Hazards

The potential for strong shaking and ground rupture is a consideration for siting, design, and operation of any dams and reservoirs within the region. Seismic hazards for a site are assessed by identifying nearby earthquake- and rupture-capable faults, and generating probability and ground acceleration maps for a site by combining the individual hazards from the known faults near the site.

The compressive stresses that formed the Yakima Fold and Thrust Belt are still acting on the area. Anticlines with greatest vertical relief and horizontal shortening are typically thrust- faulted, in which older strata are pushed up and over younger strata. Many of the faults in the Yakima Fold and Thrust Belt have had movement along them during the Quaternary Period (the last 1.8 million years). There has also been movement on some Yakima Fold and Thrust Belt faults in the Holocene Epoch (the last 11,000 years). If a fault has been active in the Holocene, it is generally believed to be capable of slipping and causing ground shaking in the present and future. Within several hundred miles of the Switzler Reservoir site, there are a number of these faults that are believed capable of producing strong ground shaking in the region.

No faults have been identified within the footprint of the proposed Switzler Reservoir and dam site. The nearest known faults to the site identified by the USGS (USGS, 2012a) are about six miles northwest of the site along the Columbia Hills anticline, seven miles northeast and nine miles north along the Rattlesnake Ridge trend. The nearest faults that the USGS considers as potential earthquake sources (Class A faults) (USGS, 2012b) include the reverse or thrust faults seven miles northeast along the Rattlesnake Ridge trend. Based on the distance to faults identified as those with potential to rupture, the fault rupture hazard at the site is considered low.

Sediments being transport by the stream in Switzler Canyon appear to consist primarily of sand and silt. When saturated, as they would be under existing and reservoir operational conditions, sandy soils may be prone to liquefaction during strong seismic shaking. At this time, there are insufficient site data to specifically evaluate this hazard to dam foundations and control structures. Liquefaction hazards, if present, can often be mitigated during construction, particularly if the liquefiable sediments are thin, which is likely the case in Switzler Canyon.

Site Geology

The basalt flows that have been mapped at the site area (Figure 4-2), as compiled by Schuster (1994) and the WDGER (2012) include, from top down, the Pomona and Umatilla Members of the Saddle Mountains Basalt and the Frenchman Springs member of the Wanapum Basalt. These basalt members are typically several tens to a hundred or more feet thick. 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 closely more 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 and morphology of the slopes.

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. These sediments consist of clay, silt, and sand and gravel and regionally range from absent to up to several hundred feet thick. These sedimentary interbeds are collectively termed the Ellensburg Formation. 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 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.

Geologic Units

Review of geologic maps and water supply well logs from the site area suggests that the site geology consists of the following units, from generally younger to older. The young units are all recent (Holocene or latest Pleistocene, and the older units are Miocene volcanic and sedimentary rocks. These units are presented on Figure 4-2, the site area geologic map, and consist of the following:

- Loess - Composed of windblown silt and fine sand that was deposited largely during the last glaciation and late glacial flooding of the region. Loess is mapped throughout much of the uplands outside of the Switzler Canyon area, and the surficial soils that support agriculture in the area. This unit is estimated to range from several feet thick to about 15 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. This unit is not shown on the regional geologic map due to its narrowness at the map scale.

- 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. Colluvium is not shown on the regional geologic map.

- 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. Talus is not shown on the regional geologic map.

- 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. These fortuitous exposures of deposits below the loess and colluvium suggest that Pasco Gravel or colluvium derived from Pasco Gravel 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 Canyon reservoir area. Umatilla Basalt is noted on the regional geologic map to be the uppermost basalt unit exposed within the canyon section and that its bottom lies near elevation 600 feet.

Mapping (Schuster, 1994; WDGER, 2012) suggests it is several hundred feet thick. 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 – Sedimentary units between the Columbia River Basalt Group are collectively known as the Ellensburg Formation. A sedimentary unit is noted 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. Regional stratigraphic analysis suggests that this sedimentary unit is the Mabton Interbed. 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 (exposures are typically limited to road cuts, etc.). 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 (in contrast to lower Alder Creek where most exposed basalt consists of large blocks of basalt within landslide debris). 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 three 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. 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. The one landslide indicated on the Figure 4-2 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. Figure 4-3 shows photographs of these shallow slope failures.

4.1.2 Preliminary Slope Stability Analysis

A preliminary numerical slope stability model was conducted to assess the impacts of immersion and seismic shaking on the materials composing the Switzler Reservoir canyon slopes. The model geometry and critical sections of the proposed reservoir site were developed using a combination of our site observations and the 20-foot contour interval topographical data presented on U.S. Geological Survey 7.5 minute quadrangle maps of the site (Figure 4-1). The stratigraphy of the underlying geologic units at the site was developed based on observations from our surface reconnaissance, including outcrops of the various geologic units visible on portions of the site slopes, and available geologic mapping (Schuster, 1994; WDGER, 2012).

The soil engineering properties assumed for the geologic units in the model were primarily derived through the back calculation of previous surficial slope failures observed on the site slopes and our experience with materials in similar geologic settings. The observed previous surficial failures provided an opportunity to calibrate and validate our preliminary modeling efforts. The derivation of the soil engineering properties was also based on our observations of the relative density, grain-size distribution, and slope configurations of the various geologic units at the site. In the absence of subsurface data suggesting otherwise, the basalt bedrock was modeled as relatively uniform and strong enough to support observed cliffs. Similarly, the glacial flood deposits (Pasco Gravel) were modeled as homogeneous, without weak zones or interbeds of silt and clay.

Due to the preliminary status of these analyses and the absence of site-specific subsurface data and testing, the soil engineering properties used for the modeling are considered conservative approximations of the actual conditions. A summary of the soil engineering properties used in the slope stability analyses is shown in Table 4-1 below.

Table 4-1 – Soil Engineering Properties Used in Preliminary Slope Stability Analyses, Switzler Reservoir

Geologic Unit	Total Unit Weight		Strength Parameters	
	Moist (pcf)	**Saturated (pcf)**	**Friction Angle (deg.)**	**Cohesion (psf)**
Loess/Colluvium (Ql)	115	120	32	1
Flood Deposits (Qgf)	120	125	35	100
Recent Alluvium (Qal)	120	125	32	1
Basalt (Mv)	140	140	40	1,000

Notes: pcf = pounds per cubic foot, and psf = pounds per square foot.

To model the proposed reservoir design conditions, we assumed a full reservoir water level at elevation 775 feet. We also assumed that the current topography will generally be maintained through reservoir construction with very minimal grading on the site slopes and at the dam site. The SLIDE stability analysis software program (Rocscience, 2008) performs slope stability computations based on the modeled slope conditions, and calculates a factor of safety against slope failure, F, defined as:

$$F = s/\tau$$

where “s” is the available shear strength of the soil and “τ” is the shear stress required for “just-stable” equilibrium. A “just-stable” equilibrium condition would result in a factor of safety of one, while an unstable condition would result in a factor of safety less than one.

The results of our preliminary slope stability analyses indicate that the site slopes are generally stable when considering large, deep-seated rotational failures due to the presence of relatively dense flood deposit soils and basalt bedrock near the surface of the site slopes. However, the relatively loose, loess/colluvium soils that mantle the majority of the site slopes are only marginally stable under the current conditions and are likely unstable under reservoir design conditions. The loess/colluvium soils were present at the ground surface across the majority of the site and estimated to range in thickness from a few feet thick to up to 15 feet thick near the crest of the slopes. The factors of safety against failure for the individual geologic units as they were modeled are shown on Table 4-2 below.

Table 4-2 – Results from Preliminary Slope Stability Analysis, Switzler Reservoir

Geologic Unit	Existing Conditions Factor of Safety(2)	Proposed Reservoir Conditions(1) Factor of Safety(2)

	Static	**Seismic(3)**	**Saturated(4)**	**Static**	**Seismic(3)**
Loess/ Colluvium (Ql)	1.0	0.7	0.3	0.7	0.5
Flood Deposits (Qgf)	1.3	1.2	0.5	1.1	0.9(5)
Basalt (Mv)	>2.0	>2.0	>2.0	>2.0	>2.0

(1) Proposed reservoir conditions include a full reservoir level at Elevation 775 feet.
(2) Factor of Safety - Minimum FS found using Spencer's method in computer program SLIDE.
(3) Pseudostatic seismic analysis based on peak ground acceleration (PGA) of 0.17g (2,475 year event)
(4) Saturated analyses include modeling the saturation of the near surface soils from heavy precipitation or irrigation runoff/seepage.
(5) The modeled failures for this case were observed within the upper few feet of the flood deposits unit.
(6) Recent alluvium (Qal) soils were only observed at the base of the slopes and were not analyzed for stability.

The modeling generally indicates that the entire thickness of the loess/colluvium is unstable under the current conditions when slope angles exceed approximately 32 degrees. When considering the proposed reservoir design conditions, the modeling indicates that the loess/colluvium is unstable when slope angles exceed approximately 22 degrees, and the upper few feet of the flood deposits are unstable under seismic conditions when slope angles exceed 36 degrees. The assumed reservoir design conditions include a full reservoir level at elevation 775 feet and a seismic event representative of the 2,475 year return period event. Additionally, the failure of loess/colluvium soils that exceed the above slope angles will propagate up the slope and over-steepen areas above the failure. This over-steepening could potentially cause additional surficial failures of loess/colluvium soils that are flatter than the maximum slope angles described above.

Geomorphic features were observed were observed during the field reconnaissance in the vicinity of the reservoir site along steep canyon slopes that appeared to be moderate-sized, deep-seated, rotational landslides (although they are not mapped as landslides by Schuster (1994) and WDGER (2012)). The deep-seated landslide-impacted slopes appeared similar in configuration and stratigraphy to the slopes within the reservoir site. Observations of the landslides from the ground surface indicated they likely extended deeper than the surficial loess/colluvium deposits with the slide planes (location of failure) located in the underlying flood deposits or basalt bedrock. It is possible that these landslides occurred due to weak zones or interbeds in the flood deposits or basalt bedrock. Weak zones may include layers of silt and clay within the flood deposits or clayey sediment deposits between basalt flows. Similar weak zones or interbeds in the flood deposits and basalt bedrock may exist within the reservoir site and were not accounted for in the modeling analyses. Additional subsurface data would be required to refine the slope stability modeling.

4.1.3 Anticipated Issues for Permitting and Construction

Construction of the Switzler Reservoir will need to consider the impacts of geology and landslides on the project and surrounding areas. Specifically, the following issues should be considered for construction, operation, and permitting:

- The embankment areas and foundation of the dam need to be geotechnically stable, or stabilized in order to construct the dam and have it provide safe service during design storm and earthquake events. The alluvial soils in the dam foundation area are potentially liquefiable. This can be mitigated, but would require additional study and design and construction costs.
- The presence of old landslide deposits within the embankment footprint suggests that some stabilization or ground improvement or relocation of the dam site would be required to develop a stable foundation and abutments.
- The stability of the existing shallow surficial landslide deposits would decrease during immersion by the reservoir. Preliminary stability analyses show a small margin of safety under existing conditions and shows failure under saturation from reservoir immersion. The most likely mode of failure would be slow sliding until equilibrium conditions are obtained (when all unstable deposits have slid into the reservoir).
- Although there are insufficient data currently to model the stability of existing older deep-seated landslide deposits, it is our opinion that they would become unstable during immersion within the reservoir. The most likely mode of failure would be slow failure. The areas that have previously failed and could fail again under reservoir operations constitute a small proportion of the area of the reservoir slopes. The majority of the reservoir slopes were immersed and drained during late glacial floods and remained stable, suggesting that they would remain stable during reservoir operations.
- Reservoir drawdowns rapid enough to allow high pore pressures to remain in soils could decrease the stability of the deposits, creating the potential for rapid failures or debris flows.
- Landslides of a significant part of soil on the canyon walls would slightly reduce the depth of the reservoir, and potentially the reservoir volume, if landslide failures were to propagate above the shoreline as is predicted by the stability analysis.
- The potential for earthquake-triggered landslides and landslide-induced large waves within the reservoir would need to be studied and addressed.
- Turbidity of water within the reservoir could increase following landslides into the reservoir.
- Subaqueous landslide debris flows, which can travel long distances underwater on very gentle gradients, would be a design and operations consideration, particularly during seismic events. If the dam was designed to draw from the

bottom of the reservoir to reduce outlet water temperature, there is potential for impacts to outlet works by subaqueous debris flows.

- Landslides within the reservoir could potentially propagate upslope or inland a short distance beyond the current edges of the canyon, effectively enlarging the canyon and losing portions of the adjacent uplands properties. Most of the land adjacent to the reservoir and canyon is used for grazing or agriculture, including center-pivot irrigated plots, orchards, and vineyards. An air photo showing recent land use around the reservoir area is presented on Figure 4-4. The potential economic impacts of loss of this land and road and other infrastructure would need to be considered.
- At the current appraisal level of understanding, the potential landslide hazard for Switzler Reservoir does not constitute a fatal flaw, as it did for Alder Reservoir (Section 3.1). However, should the Switzler Reservoir project proceed, a more thorough evaluation of the stability of slopes and the potential impacts of reservoir operation on slope stability will be required prior to project permitting, design, and construction.

4.1.4 Potential Mitigation Opportunities

The geotechnical issues introduced by constructing a dam on landslide-impacted slopes can be mitigated with appropriate design and construction. It could require extensive excavation and ground improvements to provide adequate foundation support and cutoff from seepage. Impacts of liquefiable sediments in the dam foundation area, if present, can be mitigated with ground improvement during construction.

In our opinion, there is no feasible method of preventing reactivation of landslides in and around the reservoir during filling and operation. Mitigation would require planning for long-term decreases in reservoir depth or capacity, turbidity that could impact water quality, and potential impacts on operation of the reservoir. Impacts from propagation of landslides above the reservoir could be mitigated by either establishing an increased hazard area setback or buffer zone around the reservoir, or by compensating landowners for damage or loss of use caused by landslide activity.

With the caveat that more geotechnical data and analysis would be needed prior to and during detailed design, we currently judge that the landslide hazard for Switzler Reservoir could likely be mitigated and, as such, does not constitute a fatal flaw.

4.2 Channel Geomorphology Assessment

An appraisal-level assessment of geomorphology and sediment transport of the portion of Switzler Canyon potentially affected by the proposed water storage facilities was performed based on existing data and limited field reconnaissance. Several sites along the creek alignment in the vicinity of the proposed Switzler Reservoir were evaluated and observed with respect to the presence of surface water flow, channel size and type, and sediment load and characteristics. The following sections summarize our observations of existing conditions and potential impacts to the channel that would result from implementation of the proposed reservoir project.

4.2.1 *Current Understanding of Conditions*

The proposed reservoir would be created by constructing a dam near RM 1.1. Switzler Canyon branches into two main forks at RM 1.85; an east fork, referred to herein as the mainstem, and a west fork (Figure 4-5). Our understanding of existing conditions is based on field observations of Switzler Canyon between the upstream end of the west fork of Switzler Canyon and the confluence of Switzler Canyon with the Columbia River. Field reconnaissance was performed in late September 2011, following a flood event that occurred during the spring of 2011, which resulted in significant sediment erosion and deposition throughout the basin.

For the purposes of describing potential downstream impacts of the proposed reservoir, three geomorphic reaches were delineated between the proposed dam (RM 1.1) and the mouth of the channel. The reach extents were chosen based on distinct geomorphic characteristics: channel pattern, sediment size, and geologic controls such as channel grade and canyon confinement. The proposed reservoir would likely affect these reaches in different ways or at different magnitudes. Observations of the stream channel in Switzler Canyon are presented below, followed by potential impacts to these areas under the proposed conditions. The reach extents and other relevant locations pertaining to the assessment are shown in Figure 4-5 and photographs taken during the field reconnaissance are included as Appendix B.

Site Observations

Throughout the observed portions of the channel, bedload was primarily medium to fine sand with occasional pockets of angular gravel. The primary source of bedload material is the fine wind-blown silt and sand deposits mantling the valley walls and eroded via surface runoff in other areas of the watershed.

West Fork Switzler Canyon

The west fork of Switzler Canyon was observed in several locations from the confluence with the mainstem to the upstream end of the stream channel approximately 4 miles from the mouth of Switzler Canyon. During field observation, surface water flow was present to approximately RM 1.9 in the west fork of Switzler Canyon, or approximately 1.9 miles upstream of the confluence with the mainstem. Field staff estimated the discharge at between approximately 2 to 5 cfs based on visual observation.

Upstream of the proposed maximum reservoir extent, significant deposits of fine sands from the 2011 flood event are present in the valley bottom. The channel has incised 3 to 4 feet into some of the thicker deposits (Appendix B, Photograph 1). Sloughing of the sandy materials along the valley walls was apparent in many places. Field staff observed areas where the banks were actively sloughing into the wetted channel during field reconnaissance.

At the road crossing near the upstream extent of the proposed inundation area, it appeared that a washout of the road had recently occurred. It appeared that the culvert had been replaced and the roadway had been repaired. Upstream of the newly installed culvert, the channel was lined with angular quarry spalls. On the downstream side, the culvert was perched approximately 15 feet above the creek bed (Appendix B, Photograph 2). Between the culvert and the confluence with the mainstem, the channel is typically incised into the surrounding sandy deposits, on the order of 4 to 10 feet. A standing grove of cottonwoods acts as a grade control near a pipeline crossing approximately 0.5 mile upstream of the confluence with the mainstem. The channel quickly becomes incised again downstream of the trees. Just upstream of the confluence, a shallow landslide is actively contributing fine sandy material into the stream channel (Appendix B, Photograph 3). The channel is incised 1 to 2 feet at the toe of the landslide and gradually transitions to showing no evidence of incision at the confluence.

Upstream of RM 2.2

Upstream of the road crossing (approximately RM 2.2 on the mainstem of Switzler Canyon), the stream channel bed in the mainstem was dry but several wetland plants indicate that it had recently been wetted (Appendix B, Photograph 4). The channel could not be observed directly upstream of this location due to limited access; however, it appears to be dry a majority of the year. Observation of vegetative patterns in aerial photos indicates some water may be contributed in gullies where cultivated areas drain into the valley. Just downstream of the road crossing, the channel opens into a wide, swampy wetland with stagnant or very slow moving surface water flow. There is a perched culvert where the mainstem crosses beneath the road at RM 2.2.

River Mile 1.85 to 1.1

From the confluence of the main stem and west fork of Switzler Canyon (RM 1.85) to the proposed dam location (approximately RM 1.1), the channel is wide, slow-moving, and shallow where it meanders through a wetland (Appendix B, Photograph 5). In some locations it appears to be slightly incised (1 to 2 feet) into surrounding sediment, although it could not be confirmed that these deposits were from the recent storm due to limited access to this portion of the canyon. Several areas of very slow-moving or stagnant surface water in the channel and adjacent wetland areas were observed.

River Mile 1.2 to 0.4 (Reach 1)

From the proposed dam location to approximately 0.4 miles upstream of the mouth of the canyon, the channel is wide and shallow and meanders through low terraces vegetated with wetland plants (Appendix B, Photograph 6). Some portions of the canyon, as visible in the background of Photograph 6, appear to be areas of recent deposits from the storm event where the channel meanders through wide, unvegetated sandy bars. Surface water flow in the channel is slow-moving but does not appear to be stagnant. This distinction between this reach and the reach upstream of the proposed dam may be due to a natural break in the valley grade that appears to be consistent with the valley narrowing at the site of the proposed dam.

River Mile 0.4 to 0.3 (Reach 2)

Approximately 0.4 miles upstream of the confluence with the Columbia River, the channel enters a steep, narrow, and confined section of the canyon (Appendix B, Photograph 7). The stream velocity increases through this reach. The channel is straight and appears to be confined on either side by the toe of the canyon walls (bedrock colluvium or landslide deposits).

RM 0.3 to 0.0 (Reach 3)

Approximately ¼-mile upstream of the mouth of the canyon, the valley and the channel become wider with slightly shallower grade. The channel substrate is sandy with some angular gravel. Evidence of multiple feet of sediment deposited from the storm event in the spring of 2011was observed in the channel and along the banks and floodplain where the channel has incised back through the deposits (Appendix B, Photograph 8). The landowner confirmed that multiple excavators were required to remove material deposited by the storm event in order to protect access to the pump station. A culvert beneath the gravel access road crossing the creek just upstream of the pump station appeared to have been replaced following the storm event. At the time of observation, the culvert was perched approximately 1.5 or 2 feet above the channel bed at the outlet. The mouth of the creek flows beneath a railroad trestle through a rock-armored channel into the Columbia River. No backwater effect was observed at the mouth of the creek at the Columbia River (Appendix B, Photograph 9). The water was slightly turbid during the field visit.

Site Evaluation

This study assumes that the Switzler Reservoir would be filled with Columbia River water by pumping during the winter and early spring. The water would then be released during the summer and early fall back to the Columbia River. Water would be conveyed from the reservoir to the river either through a constructed discharge pipeline or via the existing stream channel. Potential adverse geomorphic impacts to the channel and floodplain that would result from construction and operation of a reservoir in Switzler Canyon could include channel degradation in the form of bed or bank erosion, channel migration, as well as deposition of sediment downstream of the reservoir. These impacts would be greater if releases to the existing downstream channel resulted in flow rates that are higher or are sustained for a longer period than existing flow rates. It is anticipated that releases to the creek would be controlled to minimize impacts on the hydrology downstream of the reservoir. However, it is important to note that many unknowns currently exist and the threshold at which these effects may occur cannot be determined without additional evaluation. This would be an item to address in subsequent design phases should the Switzler Reservoir project proceed.

The primary unknown is the magnitude and fluctuation of discharge to the creek from the reservoir. A detailed evaluation of reservoir operations is not part of the scope of this phase of study, but can be evaluated in more detail as part of future phases of study should the Switzler Reservoir project proceed. For the sake of providing a preliminary evaluation of the geomorphic response, reservoir release is assumed to occur between May and October. In order to drain the 44,000-acre-foot reservoir during a 6-month period, an average flow rate of 121 cfs would need to be conveyed back to the Columbia River (Aspect and Anchor QEA, 2010), either through an appropriately sized discharge pipeline or through a combination of a pipeline and the existing stream channel. Actual reservoir operation will likely result in a variable release of water, with the higher peak discharge occurring during the months of July and August when the greatest demand for irrigation exists.

Potential downstream impacts to the channel are discussed with the assumption that the hydrology, including rates and fluctuation of flows, in the downstream channel would change due to reservoir construction and operation. However, as noted previously, the magnitude and timing of changes to downstream hydrology have not been defined and may be minimized by releasing most of the water through a constructed discharge pipeline. In addition, this assessment includes a general discussion of potential affects to sediment deposits along the valley walls flanking the reservoir and the sides of the valley downstream but does not include detailed results from a geotechnical perspective. Likewise, a brief discussion of potential impacts to the channel immediately upstream of the reservoir is provided, but a more detailed assessment was not a part of the scope of this study.

Comparison to Existing Hydrology

The natural hydrologic conditions of Switzler Canyon are likely characteristic of similar intermittent streams in the area (WRIA 31 Planning Unit, 2008). However, field observations indicate that irrigation return flows from agriculture upslope likely influence the hydrology in Switzler Canyon. Field staff estimated that the creek in the west fork of Switzler Canyon, which drains a relatively small area, was flowing at approximately 2 to 5 cfs, based on field observation, during a characteristically dry month of the year. The discrepancy between field observations and hydrologic conditions that would be expected from an intermittent stream in an arid area during late September suggests that most of the surface flow that was observed may be generated by return flows from irrigated agriculture adjacent to Switzler Canyon. Pools or wet vegetated gullies draining irrigated areas to Switzler Canyon were visible in the field and on aerial photos. In addition, cattails and poplars were observed growing at the edges of cultivated plateau areas high above the bottom of the canyon. These plants would not likely be present without water from the adjacent fields. Irrigation did not appear to significantly affect the upstream end of the mainstem of Switzler Canyon as no surface water flow was observed there or in aerial photography during the dry months of the year.

Stream flow gage records are not available for Switzler Canyon to our knowledge, and peak and wet-season flows in Switzler Creek are unknown. It is expected that peak stream flows in the basin occur as a result of heavy precipitation, particularly rain-on-snow events that create excessive runoff. These events typically occur between December and February in similar watersheds.

Potential Impacts to Channel Downstream of the Reservoir

Little data were available at the time of this report to support conclusions about possible geomorphic impacts to the stream channel downstream of the reservoir. The bed and bank materials are relatively fine (fine sand); thus, the threshold of motion is likely relatively low. It is apparent that the creek has the capacity to move significant amounts of sediment during high flows, as indicated by the sediment deposits observed throughout the channel following the spring 2011 flood. There are several variables that would need to be confirmed through more detailed field data gathering efforts beyond the scope of this study that could impact the channel downstream of the proposed reservoir in Switzler Canyon, including:

1. The thickness of alluvium in the valley bottom and the depth to bedrock; and
2. Subsurface geology of the material flanking the valley, which is composed of sand deposits and landslide material over bedrock, and the possibility for this material to be disturbed by downstream channel response.

In addition to these considerations, the narrow, steeper Reach 2 may have a considerably different response than the wider, flatter Reach 3 near the mouth (where significant sediment deposition occurred during the spring 2011 flood event) to changes in flow conditions that could result from reservoir operation. If reservoir releases created sustained flow rates downstream of the reservoir that are higher than existing flow rates, these conditions could accentuate the drop in energy as the channel exits the confined portion of the channel, resulting in a deposition or channel migration.

4.2.2 Anticipated Issues for Permitting and Construction

Our preliminary review of the geomorphology in Switzler Canyon suggests that reservoir implementation could result in downstream impacts if reservoir releases to the downstream channel alter the timing and rate of flows in the channel. The extent of these impacts is uncertain because reservoir operations, include timing and rates of releases to the downstream channel, have not been defined. Should the Switzler Reservoir project proceed, we expect that a more thorough evaluation of physical and biological impacts of reservoir operation will be completed as part of future phases of study prior to project permitting, design, and construction.

4.2.3 Potential Mitigation Opportunities

The potential for adverse impacts to the channel downstream of the reservoir will primarily depend on the magnitude of changes to the timing and rate of releases to the downstream channel. The following potential mitigation opportunities have been identified to address potential impacts to the channel downstream of the reservoir:

1. Regulate the reservoir release flow regime to remain below an established critical discharge magnitude and frequency; and
2. Convey discharge over the critical limit in a constructed discharge pipeline.

The most direct option to minimize impacts to the downstream channel is to regulate reservoir releases to the downstream channel to a flow rate that does not exceed a critical threshold of motion for bedload and bank sediments. Although some “flushing flows” will be desired to minimize accumulation of fine (silty) sediment and to maximize water quality, the flows should not cause detrimental bed scour. To determine an appropriate discharge, it will be necessary to collect representative bedload samples and to perform hydraulic modeling and sediment transport analyses. The results of this process may be used to estimate the frequency and magnitude of flow that may be discharged without adverse effects to the channel downstream.

If releases to the existing channel were not regulated and reservoir operation resulted in increased magnitude and duration of flow rates downstream, improvements or relocation of infrastructure in the valley downstream would need to be assessed to prevent potential damage from increased flows. For example, increased flows could require replacement of existing culverts or relocation of the access road that crosses the channel.

Allowing for regulation of reservoir releases to the channel while still providing a way for the stored water to be released to the Columbia River would likely require construction of a discharge pipeline to convey a large portion of the water released from the reservoir. Installation of a conveyance pipeline in the lower 8,500 feet of Switzler Canyon was identified in the Pre-Feasibility Assessment (Aspect and Anchor QEA, 2010). Design of the discharge pipeline would likely require some additional analysis of canyon geology and stream conditions, particularly in narrow sections of the canyon.

4.2.4 *Additional Considerations*

While describing potential impacts to the channel within and immediately upstream of the reservoir footprint were not a part of the scope of this study, it is important to note that geomorphic impacts in these areas are possible. In the stream channel immediately upstream of the reservoir inundation extent, some adjustment of the channel profile could occur that could potentially lead to channel incision, bank instability, and contribution of sediment to the channel and reservoir. Some locations where high, steep banks are actively sloughing were observed during field reconnaissance. Increased channel incision would likely lead to undercutting and increased instability of sandy deposits in the valley bottom and along the valley walls. While this is not expected to be a fatal flaw, direct effects such as channel sedimentation, and indirect effects such as instability of banks or road subgrades, should be investigated further if the proposed Switzler Reservoir moves forward.

Initial sedimentation within the reservoir is also likely and may present a concern. Upon construction and filling of the reservoir, multiple sources of sediment will likely be transported to the reservoir in a relatively short time frame from the following sources:

1. Sloughing of the shallow fine sand deposits mantling the bedrock valley walls along the boundaries of the reservoir inundation area
2. In-situ sand deposits in the valley bottom within the footprint of the inundation area
3. Alluvium and deposits mantling the hillsides contributed to the channel upstream of the reservoir and carried downstream

Saturation of the sand deposits below the water surface of the reservoir and annual filling and emptying of the reservoir will likely de-stabilize the sands along the edges of the valley, causing them to slough into the reservoir.

Estimating the initial sediment load and the sediment load over time versus the efficiency of the reservoir may provide a better understanding of how sedimentation may impact the proposed reservoir. Sedimentation may be mitigated by building a sluiceway to help flush sediment deposited in the reservoir behind the dam, or by dredging accumulated sediments on a regular basis. A low level sluice would likely only have localized sediment removal impact, primarily on sediment trapped behind the dam near the entrance to the sluiceway. Regulating the outflow when the reservoir is emptied to maximize the amount of sediment that is flushed out and downstream into the Columbia River will also help minimize the amount of deposition in the reservoir over time.

4.3 Aquatic Habitat Assessment

An appraisal-level assessment of aquatic habitat was conducted in Switzler Canyon in areas that would be affected by the construction and operation of the proposed Switzler Reservoir (area of impact). These areas included the proposed reservoir footprint and the stream channel from the proposed dam site downstream to the Columbia River (Figure 4-5). The assessment included a preliminary characterization of the area of impact using existing aerial photography, WDFW PHS data, and field reconnaissance. Field reconnaissance was completed in late September 2011 to observe existing aquatic habitat conditions. During the field reconnaissance, stream flow characteristics, stream channel conditions, and aquatic habitat features were noted. The field reconnaissance did not include any wetland delineation, stream flow measurements, or other detailed field data collection. Photographs taken in Switzler Canyon during the field reconnaissance are included in Appendix B.

4.3.1 Current Understanding of Conditions

The conditions observed in Switzler Canyon were typical of conditions that would be expected in a steep canyon draining arid, but irrigated lands of south central Washington to the Columbia River. In late September, stream flows were present only where sustained by groundwater input. Switzler Canyon branches into two main forks approximately 0.75 miles upstream of the proposed dam; an east fork, referred to herein as the mainstem, and a west fork. During the field reconnaissance, stream flows were observed from near the upstream end of the west fork to the confluence with the mainstem of Switzler Canyon and in the mainstem from the west fork down to the mouth of the canyon at the Columbia River. In the west fork of Switzler Canyon, flows were estimated to be approximately 2 to 5 cfs, based on visual observation. Measured water temperatures were consistently in the range of 11 to 12 °C. The observed channel varied in width from approximately 10 to 50 feet, but was mostly narrow and confined by the steep hillslope topography. Bed material was limited to mostly small gravel with some small gravel-sized angular basalt (<3-inch), overlaid by sandy sediment.

At the confluence of the west fork with the mainstem of Switzler Canyon, the canyon bottom widens and the gradient drops, forming a large wetland complex. Ponded water and wide adjacent beds of thistle, cattails (*Typha* sp.), and occasional Russian olive trees (*Elaeagnus angustifolia*) were observed. Water was present in the mainstem of Switzler Canyon for approximately 0.35 miles upstream of the confluence, to where the canyon road crosses the channel (RM 2.2). It appeared that the water in this reach of the main stem was ponded from the backwatering effect of the wetland complex. Upstream of the road crossing, the mainstem of Switzler Canyon narrows and the gradient increases as it becomes more confined by steep canyon topography, similar to the west fork of the canyon. No surface water was observed in the mainstem of Switzler Canyon upstream of the road crossing, although the soils were still obviously damp at the surface and wetland vegetation (i.e. cattails, thistle) was observed along the channel. The mainstem of Switzler Canyon was not accessible by road upstream of the canyon road crossing and time prevented more extensive exploration by foot; however, a narrow band of riparian vegetation could be seen extending up the main stem of Switzler Canyon from the road crossing.

Flows were also present in Switzler Canyon from the confluence of the west fork and mainstem downstream to the Columbia River. The stream channel, however, was not accessible through this reach except near the mouth at the Columbia River. As observed from the Nine Canyon orchard road high above the canyon floor, the stream channel meandered downstream from the confluence, adjusting to the large sediment deposits from the 2011 spring flood event. The riparian zone extends across the entire, low-gradient valley bottom. Clumps of cattails and dense mats of thistle fill the valley bottom along with the occasional Russian olive tree. 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, a railroad crossing, and the recent deposition and subsequent removal of a massive amount of sediment from the 2011 spring flood event. The stream channel in the downstream reach of Switzler Canyon was observed to be approximately 10 feet wide and 2 inches deep; the water was very turbid and the stream was actively cutting through the recent sediment deposits. Vegetation was mostly non-native invasive species (thistle, *Phragmites australis*). The measured stream temperature was 16°C just upstream of the confluence with the Columbia River at the canyon road crossing. At the Columbia River confluence, the measured stream temperature was 14°C.

Switzler Canyon has been impacted by human activity, including conversion of the headwater drainage area to intensively irrigated agriculture and feedlots, grazing activities, and road development within the canyon itself. There was evidence of past wildfire activity on the steep hillslopes along the main channel of Switzler Canyon. A flood event had also occurred recently in the spring of 2011, depositing large amounts of sediment in the channel from the top of the west fork of Switzler Canyon downstream to the mouth. As was noted previously, additional analysis beyond the scope of this study would be needed to confirm the origin of stream flows in Switzler Canyon. However, field observations suggest that surface flows may be sustained primarily by return flow from the irrigated lands, which would potentially result in degraded water quality, including high concentrations of nitrogen and phosphorus. Non-native thistle species appeared to be the most prevalent plant species in the riparian corridor, crowding out most native wetland-associated plant species one might expect to find adjacent to water in arid landscapes; native willow species, cattails, grasses, and possibly bulrush were also observed, although in very limited extents. Very few tree species were observed in Switzler Canyon, as would be expected in the arid habitat of WRIA 31. With the exception of a grove of five aging cottonwoods (*Populus trichocarpa*) in the west fork and a cottonwood grove of three trees near the mouth of Switzler, non-native Lombardy poplar (Populus nigra) and Russian olive (*Elaeagnus angustifolia*) predominated. No fish species, aquatic insect larvae, amphibians, or crustaceans were observed within or adjacent to the stream channel.

4.3.2 Anticipated Issues for Permitting and Construction

Available information and observations made during the field reconnaissance were used to evaluate potential impacts to aquatic habitat, instream flow conditions, and wetland characteristics that might result from construction and operation of the proposed Switzler Reservoir. Successful permitting and implementation of the project will likely require that the project avoid or minimize and mitigate unavoidable impacts. A few key issues and requirements that will likely need to be addressed have been identified.

To more clearly define impacts to aquatic resources in Switzler Canyon, a wetland delineation would need to be conducted and a mitigation plan developed to quantify the amount and quality of wetland habitat impacted by the construction and operation of the reservoir. Mitigating for wetland impacts will be challenging in the arid landscape where existing wetlands are rare and opportunities to enhance or construct wetlands are very limited. In particular, finding opportunities to replace the functions provided by the large wetland complex at the confluence of the stream forks in Switzler Canyon in equal quantity will be difficult.

A fish survey would need to be conducted in Switzler Canyon to document fish species presence, absence, and extent of use. Prior to the September 30, 2011, site visit, it was thought that Switzler Canyon only supported seasonal flows. Given the presence of flows in late September, it is reasonable to assume that fish species may be present in Switzler Canyon Creek and the West Fork. A fish survey would be helpful in establishing the extent to which degraded channel conditions, the flashy and artificially-sustained nature of the hydrology, a culvert fish passage barrier, and the relatively steep stream reach at the confluence discourage fish use in Switzler Canyon.

4.3.3 Potential Mitigation Opportunities

To address unavoidable impacts to aquatic habitats from project construction and operation, the following potential mitigation opportunities have been identified.

With the construction of Switzler Reservoir, stored water could be made available to enhance flows in Switzler Canyon Creek downstream of the proposed reservoir. As noted in Section 4.6, the reservoir will likely exhibit a measure of thermal stratification in the summer, with cooler water at the bottom and warmer water at the top. Water would likely be drawn from low in the reservoir's water column, supplementing downstream flows with cooler water during the summer. This additional and cooler water could be used as mitigation for inundated stream habitat. Given the degraded condition of the existing stream habitat that would be impacted by the construction of the reservoir, the mitigation value of providing additional instream flows would be increased by including stream habitat improvement actions downstream of the reservoir. Habitat improvements could include establishing riparian trees and shrubs, controlling non-native, invasive plant species, like thistle and phragmites, and improving the canyon road to reduce sediment delivery into the stream channel. Habitat improvement actions could also be designed and implemented in existing side channels of the Columbia River near the confluence of Switzler Canyon Creek, to enhance available off-channel juvenile salmonid rearing habitat in this reach of the Columbia River.

Along the shorelines of the proposed reservoir, shallow water areas and embayments could be created to mitigate for inundated stream and wetland habitats. In particular, wetland habitat could be constructed as in-kind and in-place mitigation for the inundation of the wetland complex at the confluence of the West Fork and mainstem of Switzler Canyon. Given the degraded condition of that existing wetland and the stream habitat, the value of the created wetland and shoreline habitat would be high compared to the impacted habitat. Wetland and riparian habitats could be constructed in adjacent drainages, given appropriate hydro-geomorphology. However, replacing aquatic habitats impacted in Switzler Canyon as a result of project construction and operations with like habitat in an adjacent drainage would have limited value as mitigation. The benefits provided to plant and animal species in Switzler Canyon that are reliant on aquatic habitat would not be replaced by mitigating for lost habitat outside of the canyon.

4.4 Terrestrial Habitat Assessment

An appraisal-level assessment of terrestrial habitat and wildlife species was conducted in the area of Switzler Canyon that would be affected by the construction and operation of proposed Switzler Reservoir project (area of impact). This area included the reservoir footprint, potential pipeline alignment, and the stream channel from the proposed dam site downstream to the Columbia River (Figure 4-5). The assessment included a preliminary characterization of the area of impact using existing aerial photography and WDFW PHS data, and field reconnaissance. Field reconnaissance was completed in late September 2011 to observe existing aquatic habitat conditions. During the field reconnaissance, existing terrestrial habitat conditions were observed, noting critical habitats such as talus slopes, riparian habitat, and native shrub-steppe habitat. The presence of native wildlife was noted when observed. The field reconnaissance did not include any detailed field investigations or measurements that would be needed to more clearly delineate or classify habitat conditions. Photographs taken in Switzler Canyon during the field reconnaissance are included in Appendix B.

4.4.1 Current Understanding of Conditions

Shrub-steppe habitat is the dominant habitat type within Switzler Canyon, while a majority of the uplands surrounding Switzler Canyon have been converted to agricultural uses. Within the canyon itself, observed shrub-steppe habitat was mostly degraded and dominated by non-native plant species, especially where past ground disturbance had occurred (i.e. road maintenance, fire, grazing, flash floods). In this arid environment, riparian habitat is very limited, as expected, and confined to the toes of slopes immediately adjacent to the stream channel in the west fork and mainstem of Switzler Canyon. However, observed riparian conditions were also degraded and dominated by non-native thistle. The infrequently-occurring trees observed were non-native Lombardy poplars and Russian olive trees. In a few instances, Lombardy poplars and cattails were observed on otherwise dry hillslopes. These outcrops of riparian plants appeared to be supported by seepage of return flow from irrigation of upslope orchards. In only two locations were native cottonwood trees observed; mid-way up West Fork (SWZ 3 – Pipeline Crossing) and near the mouth of Switzler Canyon. Documented wildlife included: coyotes, deer, raccoon, hawks, pheasants (non-native game species), crows, flycatcher, beaver, and praying mantis.

4.4.2 Anticipated Issues for Permitting and Construction

Available information and observations made during the field reconnaissance were used to evaluate potential impacts to terrestrial habitat that might result from construction and operation of the proposed Switzler Reservoir. Successful permitting and implementation of the project will likely require that the project avoid or minimize and mitigate unavoidable impacts. A few key issues and requirements that will likely need to be addresses have been identified.

An estimate of the quantity and quality of shrub-steppe habitat within the footprint of the inundation area and within any planned pipeline corridor would need to be prepared and a mitigation plan would need to be developed. Shrub-steppe habitat is listed as a Priority Habitat under the PHS Program. A survey documenting baseline conditions of the extent and composition of riparian habitat downstream of the proposed dam site might also be required.

4.4.3 Potential Mitigation Opportunities

To address unavoidable impacts to terrestrial habitats from project construction and operation, the following potential mitigation opportunities have been identified.

Given the degraded condition of the existing shrub-steppe and riparian habitat within Switzler Canyon and the extensive conversion of uplands to agricultural uses, there are opportunities for mitigating project impacts to terrestrial habitat and the native species they support with appropriate landowner support. Mitigation activities could include habitat improvement activities along the stream corridor downstream of the proposed dam site, as mitigation for inundation impacts. In particular, there are opportunities for improvements to the stream corridor immediately upstream of the railroad crossing near its mouth and to the stream corridor in the west fork of Switzler Canyon upstream of the inundation footprint. Activities could include channel reconstruction, plantings of large diameter native tree and shrub posts within the water table, and weed control. Challenges would include protecting the plantings from beaver and deer depredation, maintaining channel improvements given the potential for sediment delivery to the area, and controlling weeds given the abundant seed source.

Enhancement opportunities in the uplands are much more limited and dependent on landowner support. Generally, habitat enhancements are not consistent with agricultural objectives, so they do not typically find much landowner support adjacent to intensively farmed lands. Habitat enhancements could include placing perch poles (fence post-height) for hunting raptors, managing non-irrigated corners at fields irrigated by center-pivot irrigation systems for native grasses and shrubs, and identifying and preserving remaining native shrub-steppe habitat in those corners.

4.5 Cultural Resources Assessment

4.5.1 Background and Regulatory Context

For the purpose of completing a preliminary cultural resources review of the proposed project area, the proposed Switzler Reservoir area was located on the Juniper USGS 7.5’ Quadrangle, in Sections 17, 19, 20, 21, 29, 30, and 31 of Township 6 North, Range 30 East. The location of the project is illustrated on Figures 1-1 and 4-1.

The regulatory context for the Switzler Reservoir project is the same as for the Alder Creek Reservoir project, described in Section 3.5.1. Please refer to that section for information on applicable laws and regulations.

4.5.2 Environmental and Cultural Context

General background on the environment, archaeology, ethnography and history of the Horse Heaven area was provided for the entire Horse Heaven area, including both the Alder Reservoir area and the Switzler Reservoir project areas, in Section 3.5.2. Please refer to that section for environmental and cultural context.

4.5.3 Previous Research

Archaeological Surveys

As noted in Section 3.5.3, relatively little archaeological research has been conducted in the Horse Heaven area. Most surveys have been Section 106 compliance reviews of either linear projects (such as roads and pipelines) or small projects (such as irrigation equipment installation). The most comprehensive research projects in the area have been conducted along the shores of Lake Wallula and Lake Umatilla (Doucker ,1948; Shiner, 1950, 1955; Minor, 1991; Dickson, 1999). The surveys conducted in the 1940s and 1950s may have traversed the current project area, but researchers did not report exactly where reconnaissance occurred; whether the project area was examined during those surveys is unknown. There have been no archaeological surveys in the footprint of the proposed Switzler Reservoir, and only two within approximately a mile of the footprint (Table 4-3). Neither located archaeological materials in the area.

Table 4-3
Previous Archaeological Surveys – Proposed Switzler Reservoir Area

Author and Date	Title	Survey Methods	Findings	Distance from Proposed Project
Sharp 1997	Cultural Resources Survey for the Burlington Northern Columbia River Siding Expansion Project, Klickitat and Benton Counties, Washington	Pedestrian reconnaissance	No archaeological materials located in the portion of the surveyed area that is near the proposed Switzler Reservoir	¼ to ½ mile south of the proposed Switzler Reservoir
Dickson 1999	McNary Reservoir Cultural Resource Inventory Survey Report	Pedestrian reconnaissance	No archaeological materials located in the portion of the surveyed area that is near the proposed Switzler Reservoir	¼ to ½ mile south of the proposed Switzler Reservoir

Recorded Archaelogical Sites

There are no recorded archaeological sites in the footprint of the proposed Switzler Canyon Reservoir (Figure 3-7). Within a mile of the proposed Switzler Reservoir, one site has been recorded. Site 45BN007 was described in 1947 as a small campsite on the north bank of the Columbia River, where a canyon entering the river formed a small beach (NPS, 1947). Archaeologists with the Confederated Tribes of the Umatilla Indian Reservation could not relocate the site in 1998, and suggested that it has either been destroyed or inundated by Lake Wallula (Dickson, 1999). The site has not been evaluated for NRHP eligibility.

Although there are no recorded sites within the reservoir footprint, almost none of the area has been surveyed. Archaeological research in the area has focused on the banks of the Columbia River, but upland areas in Klickitat, Yakima, and Benton counties also host a variety of precontact and historic site types, including:

- Historic structures, equipment, homesteads, and refuse deposits related to early ranching and agriculture;
- Precontact and historic cairns (including burial cairns);
- Lithic scatters, isolates, and quarries;
- Processing sites; and
- Cave sites.

Similar sites are likely to be present within the project area as well.

Traditional Cultural Properties

There are no TCPs in the project area that are recorded at the DAHP. Tribes should be consulted as the project develops to determine whether any TCPs are present in the area that may be affected by the proposed Switzler Reservoir project.

Built Environment

There are no recorded NHRP-eligible or listed structures, bridges, or buildings in the project area.

4.5.4 Anticipated Issues for Permitting and Construction

The project will require a complete inventory of historic properties that may be affected by construction of the proposed reservoir and related facilities. Inventory should include both archaeological survey and a review of the built environment (houses, outbuildings, bridges, irrigation structures, and equipment that will be older than 50 years at the estimated time of project construction).

4.5.5 Potential Mitigation Opportunities

If NRHP-eligible historic properties will be adversely affected by the project, mitigation will be determined by the federal agencies and DAHP, in consultation with tribes and other interested parties.

4.6 Predictive Water Quality Assessment

The objective of the predictive water quality assessment is to provide a preliminary estimation of water temperature changes resulting from the operation of the proposed Switzler Reservoir, and determine the impact of water releases on the stream temperatures in Switzler Canyon from the reservoir downstream to the Columbia River. Elevated water temperatures released from the reservoir could represent a fatal flaw for the project. Evaluations on nutrients, dissolved oxygen, and eutrophication are beyond the scope of the current study. Where appropriate, recommendations for further water quality evaluations are provided for consideration in future studies.

4.6.1 Current Understanding of Conditions

Switzler Canyon is a relatively small watershed and does not contribute significantly to Columbia River flows. Hydrology and surface flows in Switzler Canyon were characterized in Section 4.2.1. Field observation and anecdotal evidence suggest that the largest flows occur as a result of rain-on-snow precipitation events. Summer and fall are typically dry with relatively small flows or no surface flows, although flows were observed during field reconnaissance in September 2011. Observed flows may be the result of return flows from irrigated area upslope of Switzler Canyon.

Switzler Canyon is not listed as an impaired waterbody in Ecology’s current water quality assessment, and does not presently have known water quality concerns. However, there are no known routine monitoring stations in the canyon and as such no water quality data is available to provide a detailed assessment of water quality. As part of this study, water temperatures were measured at various locations in Switzler Canyon during a single day of field reconnaissance in late September 2011. The locations and magnitudes of water temperatures recorded are shown graphically in Figure 4-6.

The most stringent temperature standard is the requirement to support salmonid spawning, rearing, and migration (Washington Administrative Code [WAC] 173-201A-600). For this designated use the state standard (WAC 173-201A-200) requires that the seven day average of the daily maximum temperature (7-DADMax) not exceed 17.5°C. A 7-DADMax cannot be calculated with single-event data. Nonetheless, the water temperatures measured in September 2011 do not exceed the applicable standard at any of the locations (Figure 4-6).

Field reconnaissance indicated minor periphyton blooms in areas with stagnant or very slow moving water. In general, water depths were shallow with channel bottom visible at most locations. However, evidence of recent landslides suggests that water in Switzler Canyon can be expected to be turbid at higher flows. Besides water temperature measurements, no other water quality parameters were measured during field reconnaissance. Field measurement of water quality parameters is beyond the scope of this study. Additional field data would be required to perform a more detailed surface water quality evaluation for Switzler Canyon.

4.6.2 Methodology for Predictive Temperature Evaluation

The CE-QUAL-W2 (CEQW2) model (Cole and Wells, 2008) was used to simulate hydrodynamics and temperature for both the proposed reservoir and the section of Switzler Canyon downstream of the proposed reservoir. CEQW2 is a two-dimensional laterally averaged hydrodynamic and water quality model. The model has been used at various reservoirs and lakes in the country to simulate thermal stratification and water quality (for example, Cole and Tillman, 1999; Hanna et al, 1999; EPA, 2002).

The CEQW2 model developed under this study consisted of two linked water bodies which represented the proposed reservoir and the section of Switzler Canyon downstream of the reservoir (Figure 4-7). The reservoir was made up of two branches; one which represented the mainstem and another which represented the west fork of Switzler Canyon. The section of Switzler Canyon downstream of the reservoir (referred to in this water quality evaluation as the downstream section) was defined by the proposed dam at the upstream end, and a termination point that extended approximately 5,000 feet downstream towards the Columbia River (Figure 4-8).

The model was developed to simulate temperatures in the reservoir and in reservoir releases that would be conveyed to the Columbia River either through the downstream section of Switzler Canyon or through a constructed discharge pipeline. The overall approach to characterizing the temperature regime in the reservoir and reservoir releases involved simulating the reservoir under bounding meteorological conditions and evaluating the water temperatures in the proposed reservoir and the downstream section of Switzler Canyon.

Time Period of Evaluation and Reservoir Operation Assumptions

Detailed evaluation of reservoir operation, including determination of a proposed fill and release schedule, is beyond the scope of this study. Reservoir operations will be evaluated in more detail as part of future phases of study, should the proposed Switzler Reservoir project proceed. For the sake of constructing the water quality model, the following was assumed:

- The reservoir would fill by pumping water from the Columbia River to the reservoir from November through April (6 months).
- Water would be released from the reservoir back to the Columbia River from May through October (6 months) to mitigate for Columbia River diversions elsewhere in the watershed or downstream.

The time period of evaluation was selected based on the fill and release schedule for the proposed reservoir. Although the reservoir would likely fill from November through April, these months were not modeled because the water stored in the reservoir would not be stratified and the water in storage would remain relatively cool without posing any temperature-related concerns for the downstream releases. Summer climatic conditions on the other hand would result in thermal stratification and would have the propensity to pose water quality problems, both in the reservoir and in the reaches downstream during release. Therefore, the model was run for the months of May through October, which includes the summer critical period.

Based on conceptual reservoir design developed for the *WRIA 31 Water Storage Pre-Feasibility Assessment Report* (Aspect and Anchor QEA, 2010), a maximum water surface elevation of 780 feet NGVD29 was assumed. Existing hydrological inputs to the reservoir were assumed to be negligible, and it was assumed that most of water stored in the reservoir would come from the Columbia River via pumping.

The magnitude and duration of reservoir releases have not been determined as part of this study. However, because the water quality analysis requires inputs regarding the timing and magnitude of reservoir releases, a hypothetical release schedule was developed. The hypothetical reservoir release schedule developed for this analysis is shown in Table 4-4. We expect that the flow rates that will need to be released to meet water demands and maximize the use of the water stored will far exceed natural peak flow rates currently conveyed by the existing stream channel. As was noted in Section 4.2.3, in order to mitigate the potential impact that these flows would have on channel stability and sediment transport in downstream Switzler Canyon, releases from the dam would likely have to be accomplished via two types of releases: 1) through an outlet pipeline or conveyance facility back to the Columbia River, and 2) via in-channel releases to the downstream section. The latter could help improve aquatic habitat in the downstream section.

For the purposes of the water quality analysis, a hypothetical 40 cfs peak release rate to the downstream channel was used. Reservoir operations have not been evaluated and so the actual rate of flow released from the reservoir may be less than that to maintain stable conditions in the downstream channel. Additional evaluation would be required to determine the critical discharge rate that could be conveyed by the downstream channel without adversely impacting channel stability, riparian habitat, or other existing environmental resources in Switzler Canyon. The water quality analysis assumes that flow rates above 40 cfs would be conveyed to the river via a discharge pipeline. The water quality analysis also assumes that releases through the discharge pipeline would be withdrawn from the model segment directly upstream of the dam (segment 8) and over an elevation range of 455 to 480 feet NGVD29.

Table 4-4

Assumed Reservoir Release Schedule for Water Quality Model

Month	Total Flows Released (cfs)	Conveyed to Columbia River Via Pipeline (cfs)	Discharged to Columbia River Via Stream Channel (cfs)
May	12	0	12
June	110	70	40
July	240	200	40
August	240	200	40
September	110	70	40
October	12	0	12

4.6.3 Model Development and Verification

The model domain was defined within the reservoir pool boundary line. The reservoir pool boundary specifies the area of inundation and is defined by the 780 foot elevation contour, consistent with the proposed pool elevation. Figure 4-7 provides a depiction of the pool boundary line and model segmentation (as discussed below).

The model grid was defined by three geometric parameters, which ultimately define the storage volume of each water body: 1) segment length, 2) layer widths defined at regular vertical increments and 3) layer thicknesses that specify the magnitude of the vertical increments.

The area defined by the reservoir pool was divided into nine longitudinal segments (Figure 4-8 – active model segments are shown in blue, gray segments are dummy segments required by CEQW2 between branches and at the boundaries). The mainstem (branch 1) and the west fork (branch 2), with nine and four segments respectively, were defined as Water body 1 in the CEQW2 grid. The downstream section (Water body 2) consisted of three branches (branches 3-5), each made up of four segments. The lengths of all model segments ranged from approximately 700 to 4,000 feet. The segments were oriented longitudinally in the direction of surface water flow.

ArcGIS® was used to establish elevation-volume relationships for each segment at 9.84-foot (3-meter) increments. The cumulative volume represented at each elevation over all the model is shown in Figure 4-9. This was verified against the reservoir elevation-volume relationship developed as part of the *Pre-feasibility Storage Assessment* (Aspect and Anchor QEA, 2010). The model segment widths ranged from approximately 200 to 1,700 feet corresponding to the 780 foot contour.

Initial Conditions

The CEQW2 model requires specification of initial water depth and temperature conditions. As discussed above, it was assumed that the proposed reservoir would ultimately fill to an approximate elevation of 780 feet by the beginning of May, which corresponds to the beginning of the model period. An initial water temperature of 10.5^{0}C was specified for both water bodies over the entire water column. This value was derived from historical temperatures recorded in the Columbia River at Umatilla (Ecology Station 31A070) in the first week of May.

Boundary Conditions

The CE-QUAL-W2 model requires several inputs for simulating hydrodynamics and water temperature. The hydrodynamic simulation requires specification of inflows and outflows and/or water surface elevations at model boundaries. Temperature simulation requires meteorological data including wind speed, air temperature, cloud cover, and dew point temperature. Surface heat fluxes are estimated from this information. In addition, the model requires specification of temperature of inflows.

Inflows and Outflow

The primary driver of the model is the controlled release of water from the reservoir (Table 4-4). In addition, minor inflows at branches 1 and 2 were specified to prevent drying out of the shallow upstream segments of the inundation area following releases over summer. A constant inflow of 10 cfs was specified at branch 1 over the course of the model simulation, while a constant inflow of 5 cfs was specified for branch 2. In the absence of flow measurements, these small inflows were estimated through trial and error to provide a minimum flow needed to keep the upstream segments inundated through the model simulation period.

Temperature of Inflows

Inflow temperature data is not available. The only measurements available were those made during field reconnaissance in September 2011 (discussed in Section 4.6.1). In the absence of additional data, a constant value of 10.5 °C, which was used as the initial temperature for the reservoir in May, was assumed to hold throughout the year. This assumption is reasonable because the inflows that enter branches 1 and 2 over the summer period are predominantly derived from groundwater, and have short travel paths. Therefore, these inflows will have limited opportunity to absorb solar radiation prior to reaching the reservoir. Stream temperatures recorded with a handheld thermometer during field reconnaissance in September 2011 (Figure 4-6) were comparable to the value specified at the boundaries. In any case, these inflows are minor contributors of flow as well as heat to the overall reservoir pool and the predicted temperatures in the reservoir are unlikely to be sensitive to these inflows.

Meteorological Boundary Conditions

Meteorological data collected at two National Oceanic and Atmospheric Administration stations, Tri-Cities (ID: 727845) and McNary Dam, were obtained from the National Climatic Data Center (NCDC). The McNary Dam station was moved in 1954 and in 2007 (ID: USC00355389 from 1948 to 1954, ID: USC00455231 from 1954 to 2007, and ID: USC00355392 from 2007 to 2011) to new locations within 2 miles of each other and are approximately 10 miles west of the project site, as shown in Figure 4-10. The Tri-Cities station is located approximately 22 miles north of the project site.

The data coverage between these stations differed: McNary Dam station had long-term daily temperature data from 1948 to present but other parameters were not available; Tri-Cities station dataset was comprehensive and provided a complete set of parameters needed for the model, but the period of this dataset was limited from 2007 to 2011. In order to determine whether the Tri-Cities data was representative of conditions at the project site, temperature data from the Tri-Cities station from 2007 through 2011 was compared to the data from the McNary Dam station from the same period. The McNary Dam station is closer to the project site and is likely to be more representative of meteorological conditions at the project site. As discussed in Section 4.6.2, the temperature regime in the reservoir was evaluated for the summer period (May through October). Therefore, averages of daily maximum and minimum air temperature from May through October were calculated from the hourly data at the Tri-Cities station, and compared to the corresponding observations at McNary Dam station.

Time series of the calculated summer averages at the two stations are shown in Figure 4-11. The inter-annual trends between the two data sets were comparable, with a slightly larger range indicated at the Tri-Cities station. But the differences in the summer average daily maximum and daily minimum temperatures were less than 2.0 °C and 1.9 °C respectively. Considering that this is a preliminary evaluation and that the data set at Tri-Cities is comprehensive, for the purposes of this evaluation, the meteorological record at Tri-Cities was deemed reasonably representative of conditions at the project site.

To determine representative years for simulation of reservoir temperatures, a probability plot of summer averages of daily maximum temperature was developed using both McNary and Tri-Cities data (Figure 4-12). Three years from the period of record at Tri-Cities were selected such that warm (2009), cool (2010), and moderate (2011) conditions were represented. The summer average of the daily maximum temperatures recorded at Tri-Cities on these years represented approximately the 95th, 40th, and 55th percentiles respectively of the summer average air temperatures from 1948 to 2011 at McNary Dam station.

The hourly data at the Tri-Cities station corresponding to the model simulation periods in 2009, 2010, and 2011 are shown in Figures 4-13a, 4-13b, and 4-13c. These were used as the meteorological forcing functions in the CEQW2 model.

Model Parameterization

The default hydrodynamic parameters and recommendations in CEQW2 user's manual were used to develop the hydrodynamic simulation in the reservoir section. For the downstream section the Manning's coefficient and slopes were adjusted such that shallow water depths (about one to two feet) were simulated in the model. The stream depths are likely to be smaller over the summer period. However, without site-specific data it was not possible to calibrate the model with greater accuracy. Minor differences in water depths are unlikely to produce substantial differences in the temperature simulation. For water temperature simulation, parameters that affect heat exchange are the most critical. Parameters that control wind function were selected based on the recommendations in the manual for small reservoirs (Cole and Wells, 2008). Light extinction coefficients were set to the default values recommended in the model. Wind sheltering coefficients were selected to range from 0.5 to 0.75 depending on segment width based on observations during field reconnaissance and professional judgment. Topographic shading was determined from the ground surface elevation contours. Most of these parameters could not be ascertained due to data limitations. The uncertainty arising from the unknown values of the true parameters on the simulated temperatures were determined through sensitivity analysis.

Model Verification

A model simulation was set up with the meteorological conditions corresponding to the moderate temperature year, discussed earlier, to verify the model pool elevation changes, storage, and temperature depth profiles simulated in the model. The fill and release schedules discussed previously were applied to drive this simulation.

Model simulated water surface elevations in the proposed reservoir are shown in Figure 4-14 and illustrate that patterns of decline in the water surface elevation over time are consistent with the withdrawal and outflow schedule described in Table 4-4. The simulated declines in pool volume are consistent with those expected from the design storage curves.

Average water temperatures simulated at the top 3 meters (9.84 feet) of the reservoir and the bottom 3 meters of the reservoir are shown in Figure 4-15. Surface water temperatures ranged from 19 to 24°C from mid-June (when stable stratification has set in) to mid-September (when stratification begins to dissipate). The average and range of water temperatures observed at WDOE's water quality station on the Columbia River at Umatilla (31A070) are also shown for comparison. Considering that this station is immediately downstream of the McNary Dam, the observed temperatures reflect the temperature of water released from Lake Wallula, which is impounded by the McNary Dam. The simulated patterns in temperature for the proposed reservoir are generally comparable even though the range represented in the historical data is cooler. This can be explained from the fact that a much larger volume of water is impounded in Lake Wallula (44,000 ac-ft versus 1.35 million ac-ft), which would require far greater solar heating. Moreover, Lake Wallula is considered a run-of-the-river reservoir with a much shorter retention time that could also contribute to reduce solar heating.

Figure 4-15 shows that the water temperature at the bottom of the reservoir remains stable through the summer but becomes warmer towards the end of summer and fall due to the declining water levels and the smaller volume of water that is exposed to solar heating. By the end of September, the water temperatures at the surface and bottom of the reservoir are nearly the same, signifying that reservoir has turned over.

Model simulated depth profiles of temperature under the meteorological conditions corresponding to the moderate temperature year are shown at model segment 8 (i.e. segment upstream of the dam) on the 1st and 15th of each month over the simulation period in Figure 4-16. The depth profiles show the onset, persistence, and break-up of thermal stratification in the reservoir consistent with the patterns observed in other similar reservoirs. The changing water surface elevations over time reflect the continuous withdrawal/release of water over the summer. The depth profiles show that the withdrawal causes the thermocline to sink at a rate greater than it normally would have had the water level remained fixed. In most temperate lakes and reservoirs of comparable depth where the water levels are relatively stable, the thermocline would be maintained at a relatively constant depth through the summer until early fall when it begins to sink rapidly resulting in a turnover. Patterns in the temperature depth profiles similar to those presented here were observed at the Pine Flat Lake in California when substantial declines in water levels occurred due to withdrawals for irrigation (Cole and Wells, 2008).

While an explicit site-specific calibration of the model is not yet possible, the results above indicate that the model simulations are consistent with observations from other sites that experienced comparable meteorology or operations. This indicates that the assumptions used in developing the model are reasonable. For the purposes of this preliminary evaluation, this level of accuracy is deemed sufficient.

4.6.4 Model Application

As discussed in Section 4.6.3, two runs were performed with 2009 and 2010 meteorological conditions that represented warm and cool years, respectively. The flow releases used for the moderate temperature year simulation were carried forward to the two bounding runs. Therefore, the only input file that differed between the model runs was the meteorological input file.

Depth profiles of simulated outflow temperature at the segment upstream of the dam (segment 8) are provided on the 1st and 15th of every month of the simulation period for the moderate, cool, and warm years (Figure 4-17). The temperature profiles simulated for the warm year shows that the stratification sets up earlier and is slightly stronger than the other two meteorological conditions. Mid-summer surface water temperatures were warmer by about 2 °C for the warm year. Bottom water temperatures remained stable and comparable under all three conditions, with the warmer year producing a relatively rapid increase in temperature in early fall when the water levels are lower. The depth profiles show that for a brief period in early fall, water temperatures remained elevated throughout the water column for all three conditions. This is a result of continuous withdrawal of cold waters from the bottom, which enables more rapid mixing of the warmer waters from the surface, resulting in an earlier turnover.

Effect of Reservoir on Downstream Temperatures

For the section of Switzler Canyon downstream of reservoir, the temperature under existing conditions (without a reservoir) was simulated by introducing a constant flow of 15 cfs at the upstream segment. In order to specify the temperature entering this section, data collected at the nearby Alder Creek (WDOE Station 31C012) in 2009 and 2010 were used to develop a time series of temperatures. For the purpose of this simulation the existing conditions were simulated using 2011 (i.e. moderate year) meteorological conditions.

In Figure 4-18, the 7- DADmax temperatures simulated in the downstream section of Switzler Canyon under the moderate, warm, and cool years under with-reservoir conditions are shown compared to the representative temperature regime established under existing conditions (without a reservoir) for a moderate year. The figure shows that the temperatures in the downstream section are likely to benefit over majority of the summer due to the release of colder waters from the reservoir. Towards the end of summer and in early fall when the lower water levels in the reservoir and the weakened stratification results in warmer waters, the temperatures in the downstream section are predicted to be higher than those simulated under existing (without reservoir) conditions and could exceed the 7-DADmax standard for salmonid spawning, rearing, and migration. However, the period of exceedance is predicted to be relatively short and occurs in the fall. The outflows from the reservoir will ultimately reach the Columbia River, either through a discharge pipeline or the downstream stream channel. In either case, localized effects (i.e. temperature declines in summer and slightly warmer temperature in fall) are possible in the Columbia River within the mixing zone of the discharge, but considering the small flow volumes in the discharge relative to the overall volume of water conveyed in the corresponding reach of the Columbia River, the effects on the Columbia River temperature are not likely to be measurable outside of a small mixing zone.

4.6.5 Discussion

The results of hydrothermal modeling showed that surface temperatures in the reservoir can exceed 20 °C during summer and early fall even under relatively cool meteorological conditions. This is not uncommon in smaller reservoirs and lakes in warm, arid climates. Furthermore, when waters released to the downstream section of Switzler Canyon are withdrawn from the bottom layers, which were shown to remain cold most of the summer, significant downstream benefits can be expected. Warmer waters in the downstream section were predicted for the late summer and early fall, leading potentially to some violations in the temperature standards for the designated uses. However, such exceedances were predicted to occur over a relatively short period compared to the summer period over which thermal benefits were predicted.

Based on the preliminary evaluations above, the temperature regime in the reservoir is not expected to pose a fatal flaw. Several simplifying assumptions were made in this study, including estimated upstream flows and temperature, approximation of meteorological conditions from a relatively distant station, simplistic representation of the segments downstream, and simplified parameterization for light extinction. The implications of the most important assumptions on the determination of no fatal flaw are discussed below:

Meteorological Forcing Functions – The model employed meteorological dataset from Tri-cities. Air temperatures recorded at Tri-cities were shown to be generally representative of the conditions at the Switzler Canyon. However, wind speed comparisons could not be made because of a lack of paired data set at the meteorological stations close to the canyon. If the wind speeds at Tri-Cities are not representative of the site conditions then the simulated temperatures could be different. It is recommended that future studies consider wind-speed measurements at the canyon, with comparison to the Tri-Cities data, to establish the applicability of the wind speed data used for modeling.

Light extinction coefficient – A sensitivity analysis indicated that the temperature profiles are moderately sensitive to the background light extinction coefficient. The light extinction coefficient could not be established definitively at this stage because such a refinement would require a detailed evaluation of suspended solids loading and plankton activity in the reservoir, which was beyond the scope of this work. It is recommended that future studies address refinements to assumed light extinction coefficient by taking these factors into consideration.

Withdrawal Elevation – In this evaluation it was assumed that water would be withdrawn from the bottom of the reservoir, primarily because that is the depth with the coolest water temperature. However, bottom waters can have reduced dissolved oxygen (DO) due to oxygen demand exerted by the decomposing organic matter in the sediments. Evaluation of DO was beyond the scope of this study. It is recommended that future studies consider an evaluation of DO dynamics to provide a better basis for selection of the withdrawal elevation.

Other Water Quality Parameters – A detailed evaluation of nutrients and eutrophication was not part of the scope of this study. Field observations indicate that existing surface flows in the canyon may be at least partially generated by return flow from irrigation of agricultural activities upslope of Switzler Canyon. Agricultural return flows may have high nutrient loads. If nutrient loads to the reservoir are high then there is a potential for increased primary production, which in turn can have implications on the reservoir turbidity, dissolved oxygen, and pH, and may potentially limit discharges back to the Columbia River. If the project advances to the next phase, collection of nutrient data is recommended to assess whether nutrients loading to the reservoir is likely to pose a problem.

4.7 Conclusion for Switzler Reservoir

Based on the information described above for each technical discipline, we identify no fatal flaws with the proposed Switzler Alder Reservoir. There would be a range of technical issues to address before Switzler Reservoir could be permitted and constructed; however, at this appraisal stage of assessment, we judge that none of the issues constitute a fatal flaw.

We recommend proceeding with Phase 2 engineering for Switzler Reservoir.

5 Conclusions and Recommendations

Based on the information generated from the collective technical discipline studies of the Phase 1 appraisal assessment (geologic stability, channel geomorphology, aquatic habitat, terrestrial habitat, and archaeologic resources), the proposed Alder Reservoir is concluded to be fatally flawed as a result of landslide hazards. The canyon walls of the proposed Alder Reservoir currently contain numerous, mostly ancient, landslides. We conclude that repeated filling and emptying of the proposed Alder Reservoir – repeatedly saturating the landslide deposits – would create an unacceptable risk for re-activating the existing landslides and initiating new landslides. Such landslides could impair use of the reservoir, and, if new landslides are triggered, also create substantial damage and loss of land within properties surrounding the reservoir. Given the magnitude of the landslides within the proposed Alder Reservoir, we conclude there are no cost-effective means to mitigate the landslide risk.

No fatal flaws are identified for the proposed Switzler Reservoir in terms of geologic stability, channel geomorphology, aquatic and terrestrial habitat, archaeological resources, or predictive water quality. The Phase 1 studies identify numerous technical issues to address before Switzler Reservoir could be permitted and constructed; however, at this appraisal stage of assessment, we judge that none of the issues constitute a fatal flaw.

We recommend that the proposed Switzler Reservoir proceed into Phase 2 of the appraisal assessment, in which refined engineering assumptions and cost estimates are developed and optimal uses of the stored water identified. The Phase 2 assessment will provide a substantially improved understanding of whether the proposed project economics (i.e., required price of new mitigated water rights made available by the project) constitute a fatal flaw.

5.1 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. It is intended for the exclusive use of WRIA 31 Planning and Advisory Committee for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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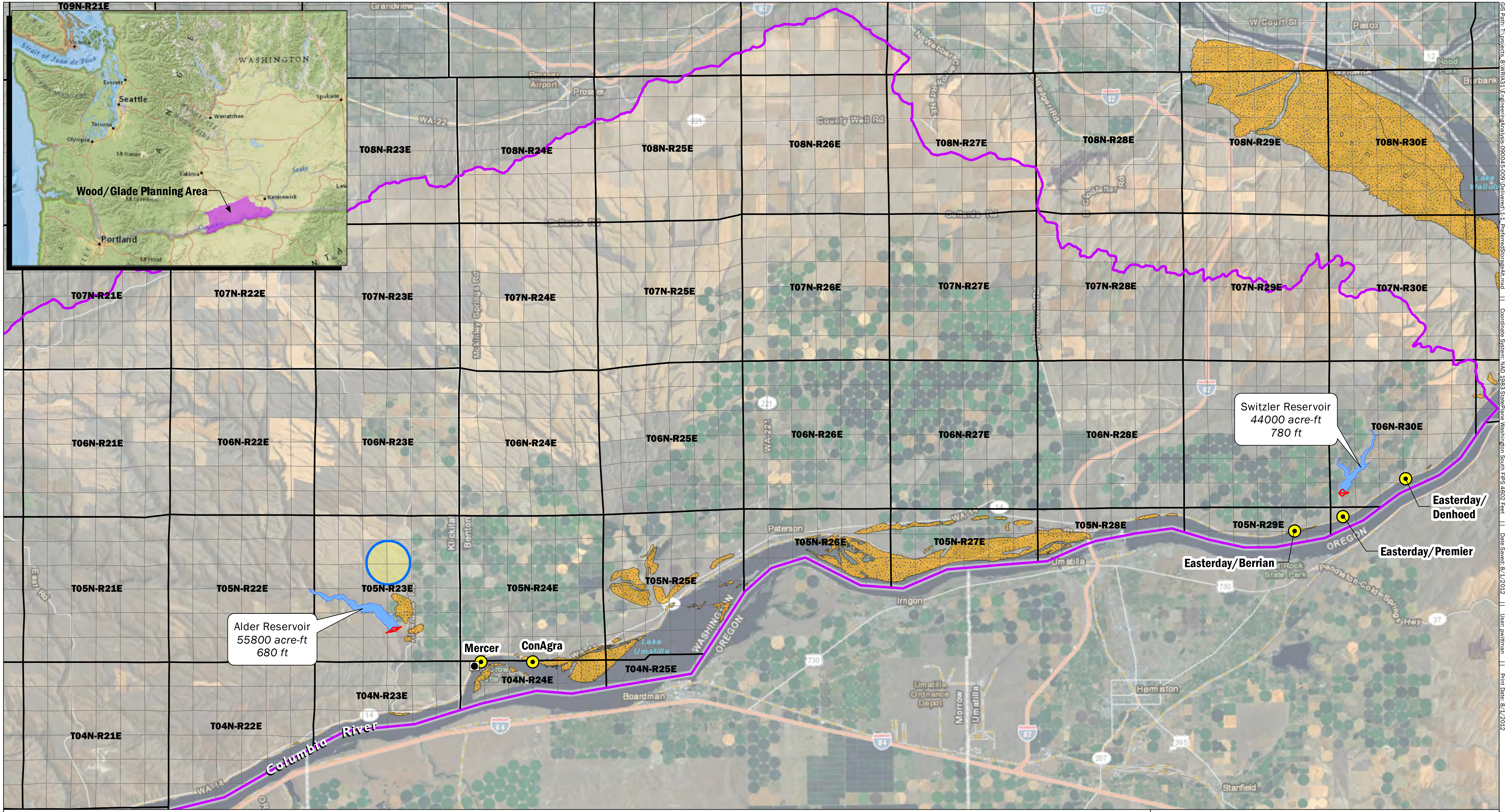

Basemap Layer Credits | | National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
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Preferred Storage Alternative

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING

AUG-2012
PROJECT NO. 090045
BY: PPW
REV BY: PPW
FIGURE NO. 1-1

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Figure 2-1
Hydroelectric Potential - Alder Creek Reservoir

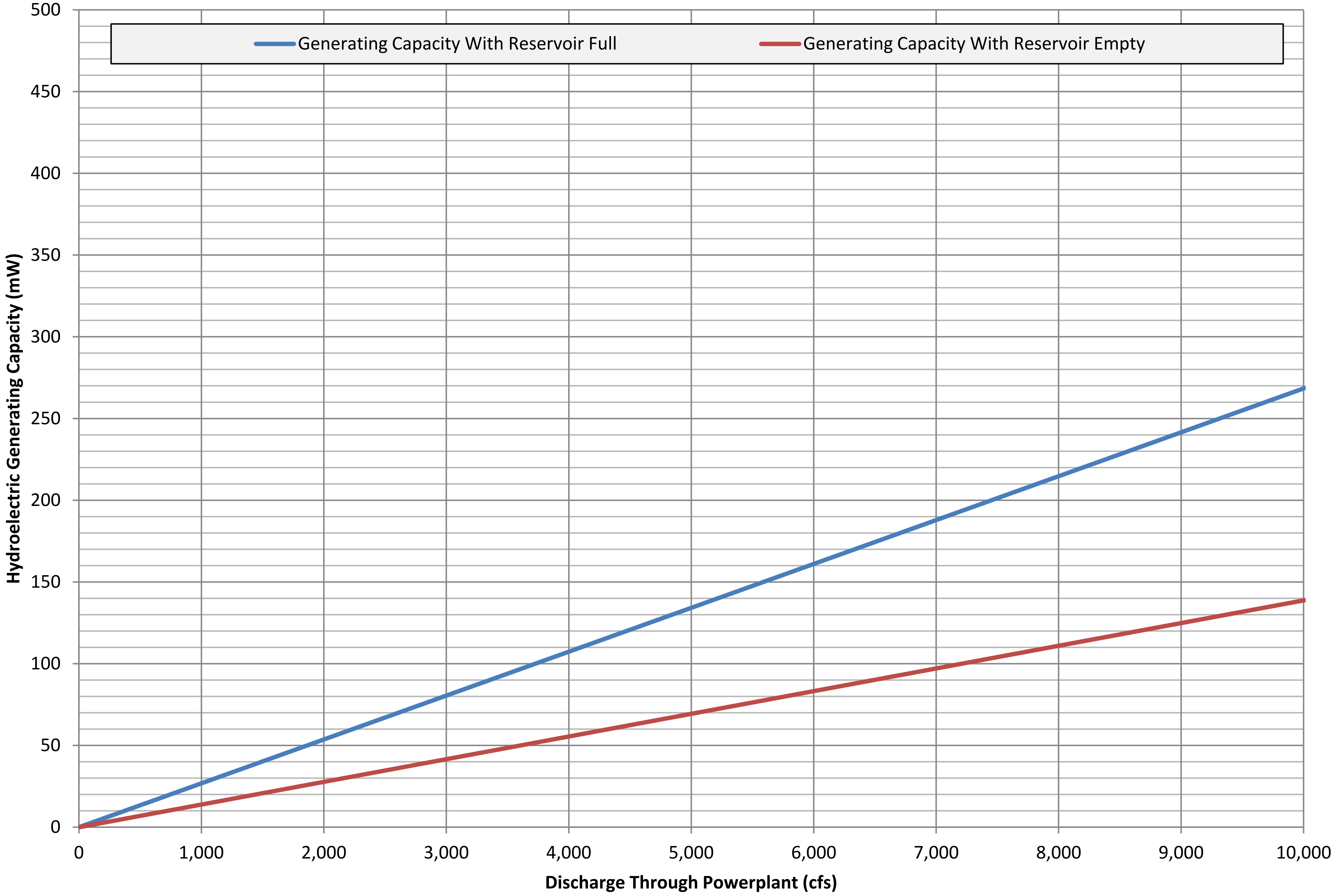
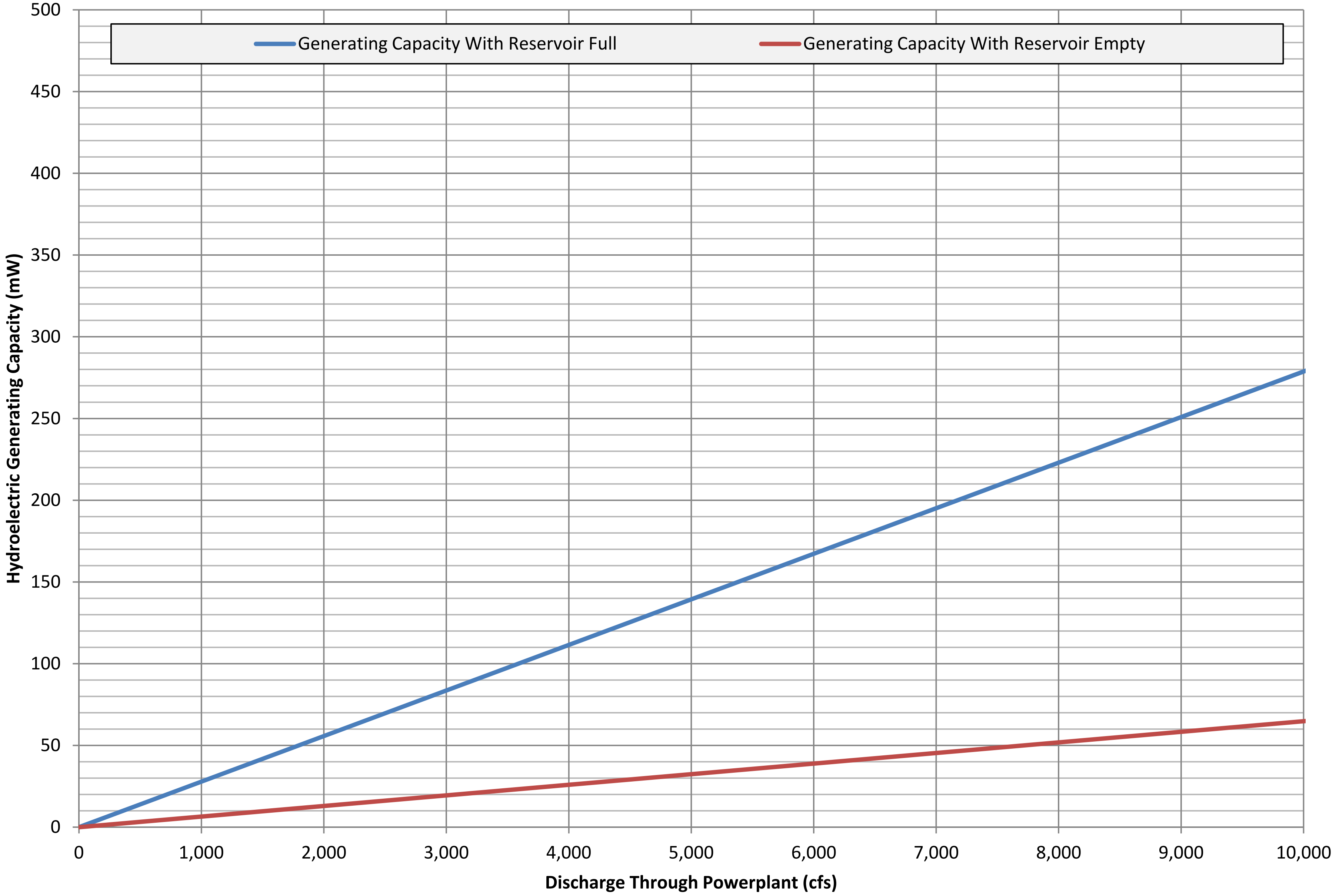
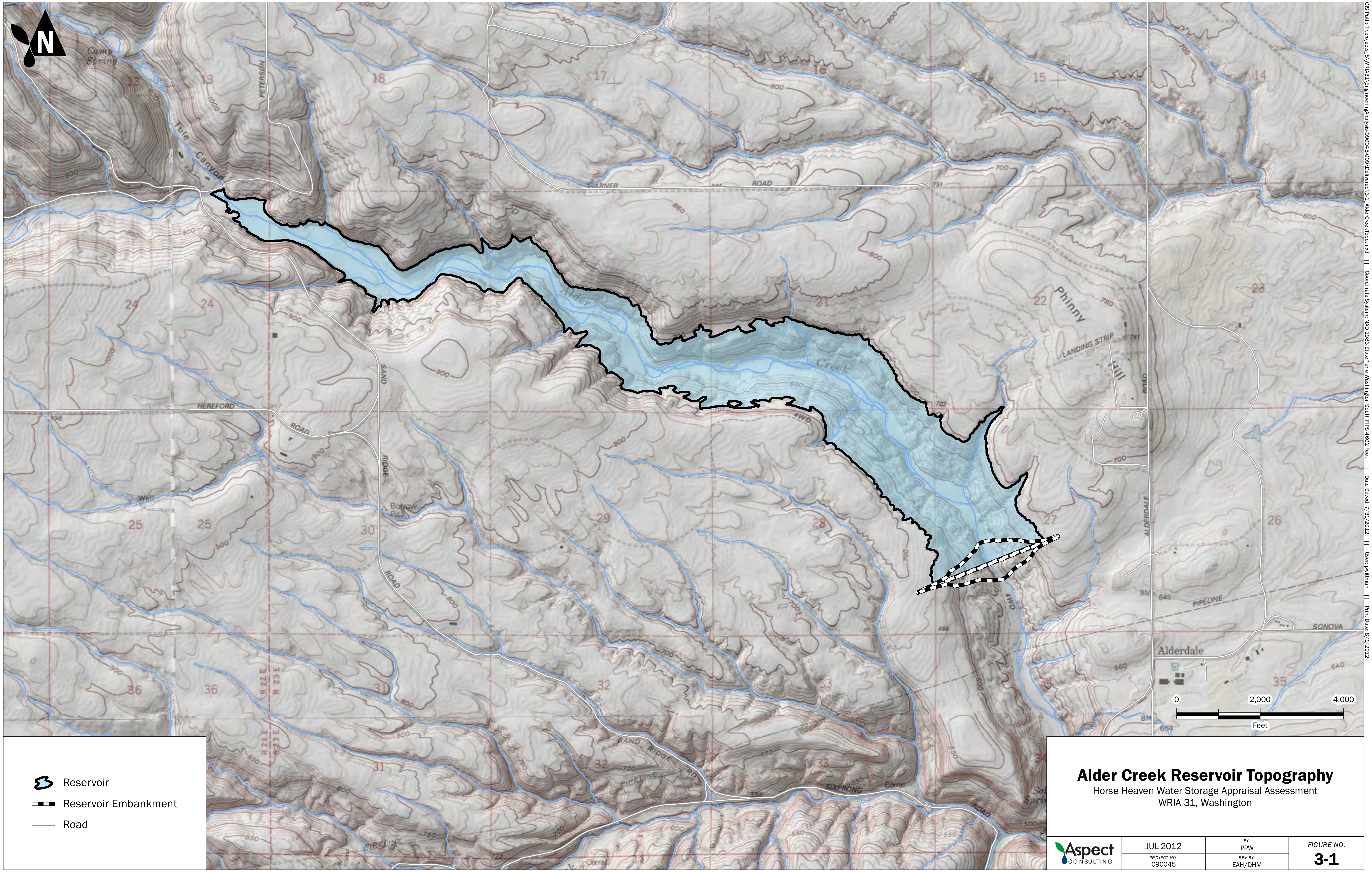


Figure 2-2
Hydroelectric Potential - Switzler Canyon Reservoir





- Reservoir
- Reservoir Embankment
- Road

Alder Creek Reservoir Topography

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	JUL-2012	BY: PPW	FIGURE NO.
	PROJECT NO. 090045	REV BY: EAH/DHM	3-1

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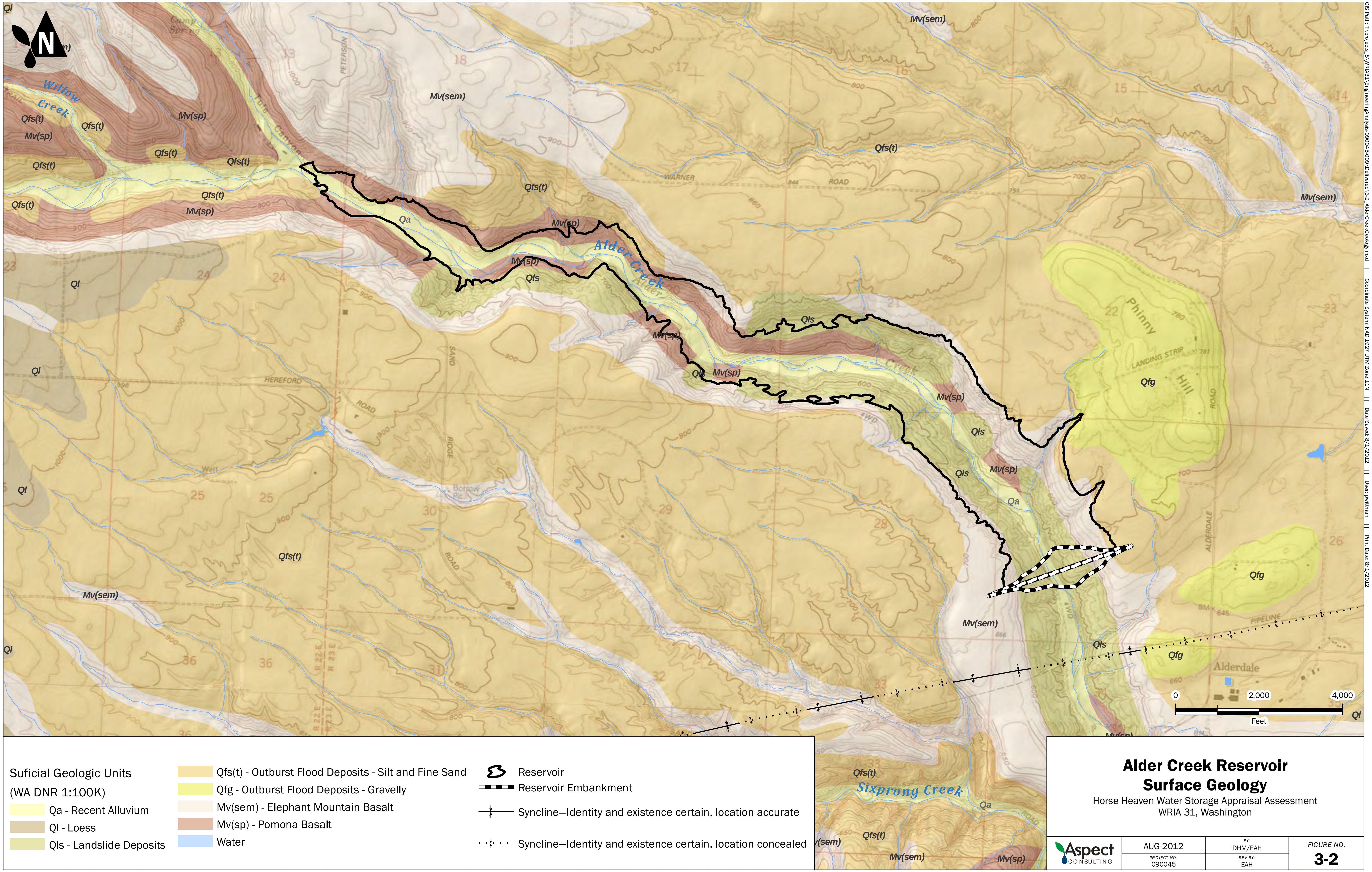

Suficial Geologic Units
(WA DNR 1:100K)

Qa - Recent Alluvium
Ql - Loess
Qls - Landslide Deposits
Qfs(t) - Outburst Flood Deposits - Silt and Fine Sand
Qfg - Outburst Flood Deposits - Gravelly
Mv(sem) - Elephant Mountain Basalt
Mv(sp) - Pomona Basalt
Water

Reservoir
Reservoir Embankment
Syncline—Identity and existence certain, location accurate
Syncline—Identity and existence certain, location concealed

Alder Creek Reservoir
Surface Geology

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	AUG-2012	BY: DHM/EAH	FIGURE NO. 3-2
	PROJECT NO. 090045	REV BY: EAH	

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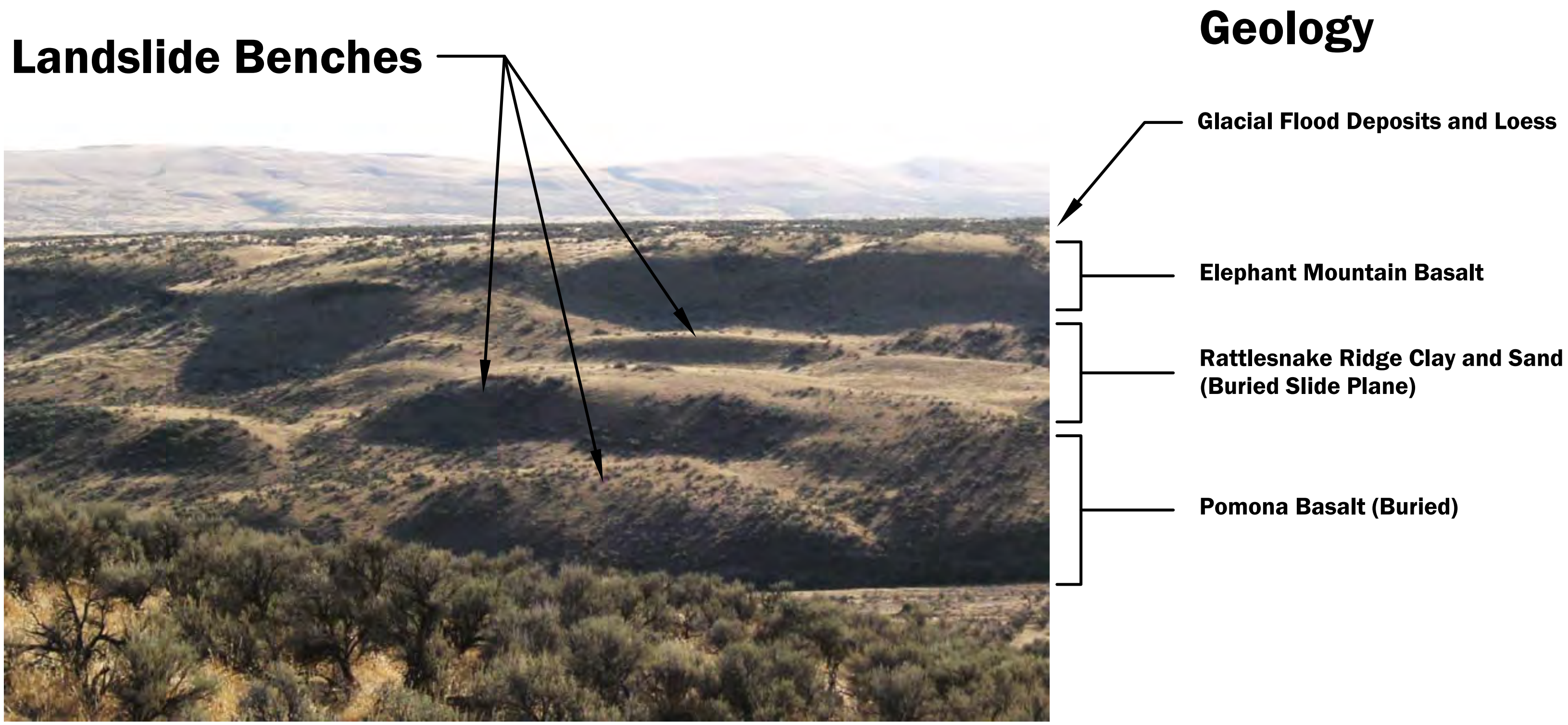
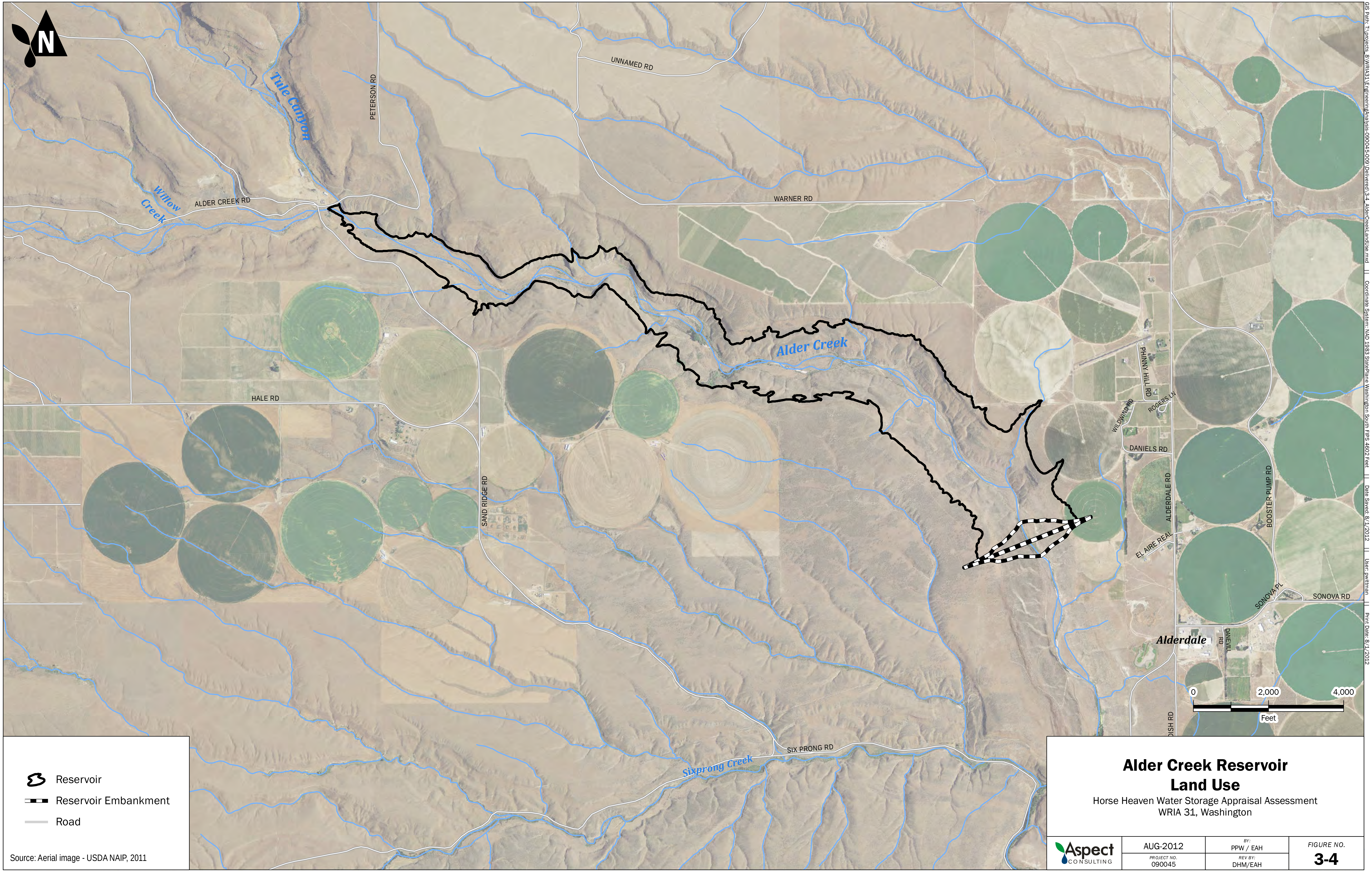


View to southeast at proposed right dam abutment area. Irregular benches and hummocky topography is a result of landslide failure of the Elephant Mountain Basalt unit over weak clay beds. Landslide deposits have covered the middle and lower slope units.

Lower Alder Creek Reservoir Landslides

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	APR-2012	BY: DHM/SCC	FIGURE NO.
	PROJECT NO. 090045	REV BY: SCC	3-3



Source: Aerial image - USDA NAIP, 2011

Alder Creek Reservoir Land Use

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	AUG-2012 PROJECT NO. 090045	BY: PPW / EAH REV BY: DHM/EAH	FIGURE NO. **3-4**

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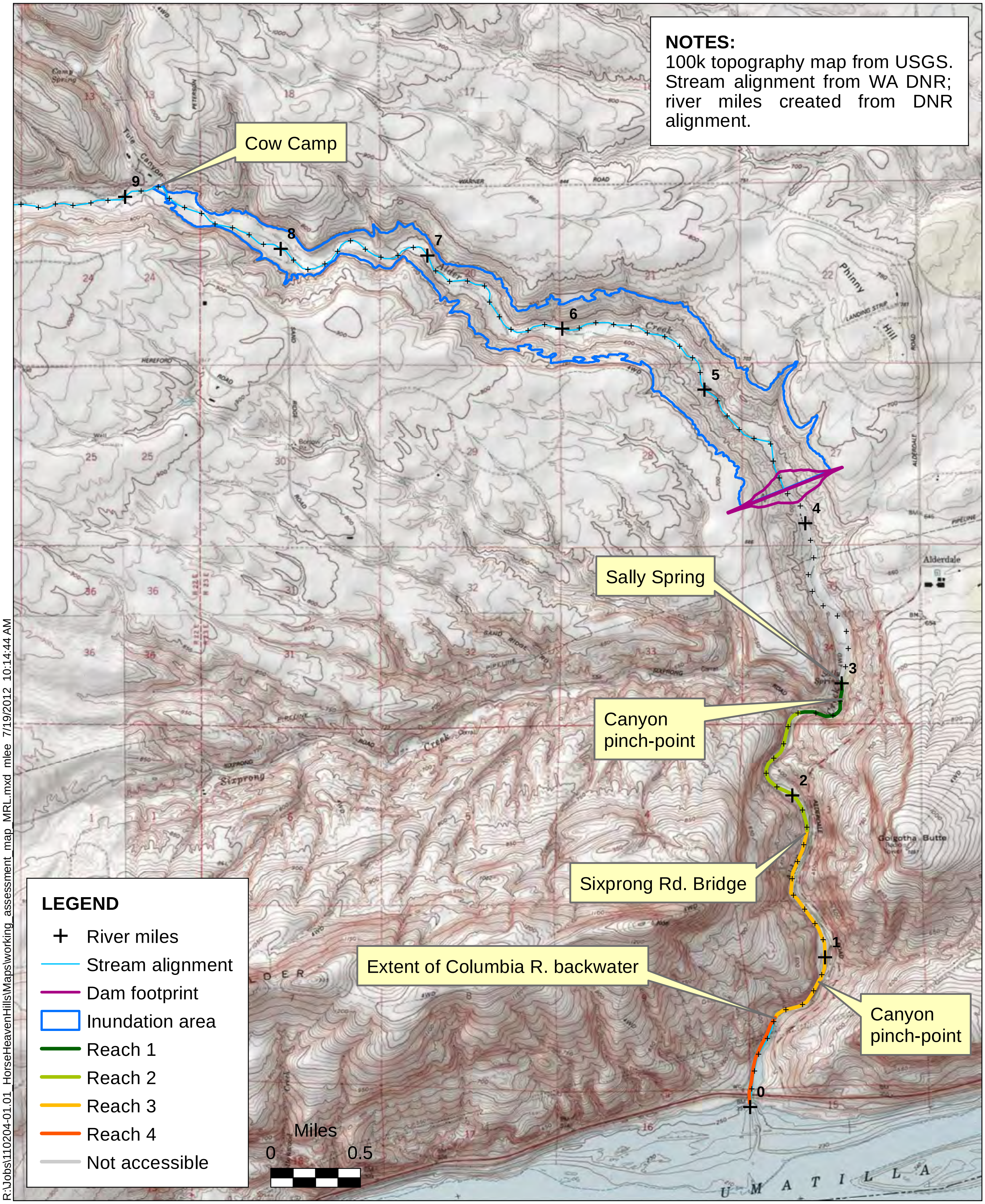

NOTES:
100k topography map from USGS. Stream alignment from WA DNR; river miles created from DNR alignment.

LEGEND
- + River miles
- Stream alignment
- Dam footprint
- Inundation area
- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Not accessible

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Figure 3-5
Alder Creek Geomorphic Reaches
Phase 1 Report
Horse Heaven Water Storage Appraisal Assessment

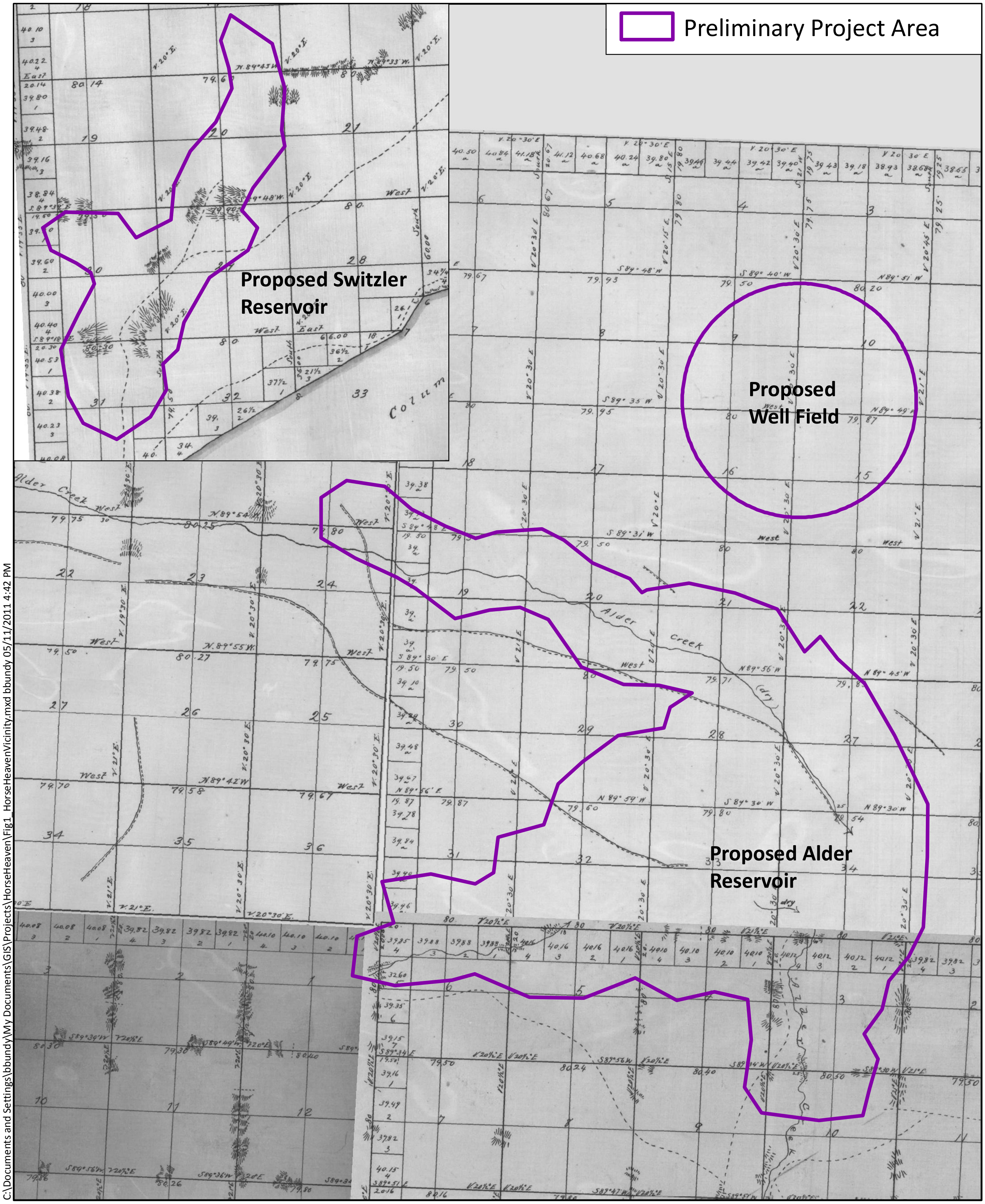

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Figure 0πC

1858-67 General Land Office Maps of Project Area

Archaeological Assessment

Horse Heaven Water Storage Appraisal Assessment

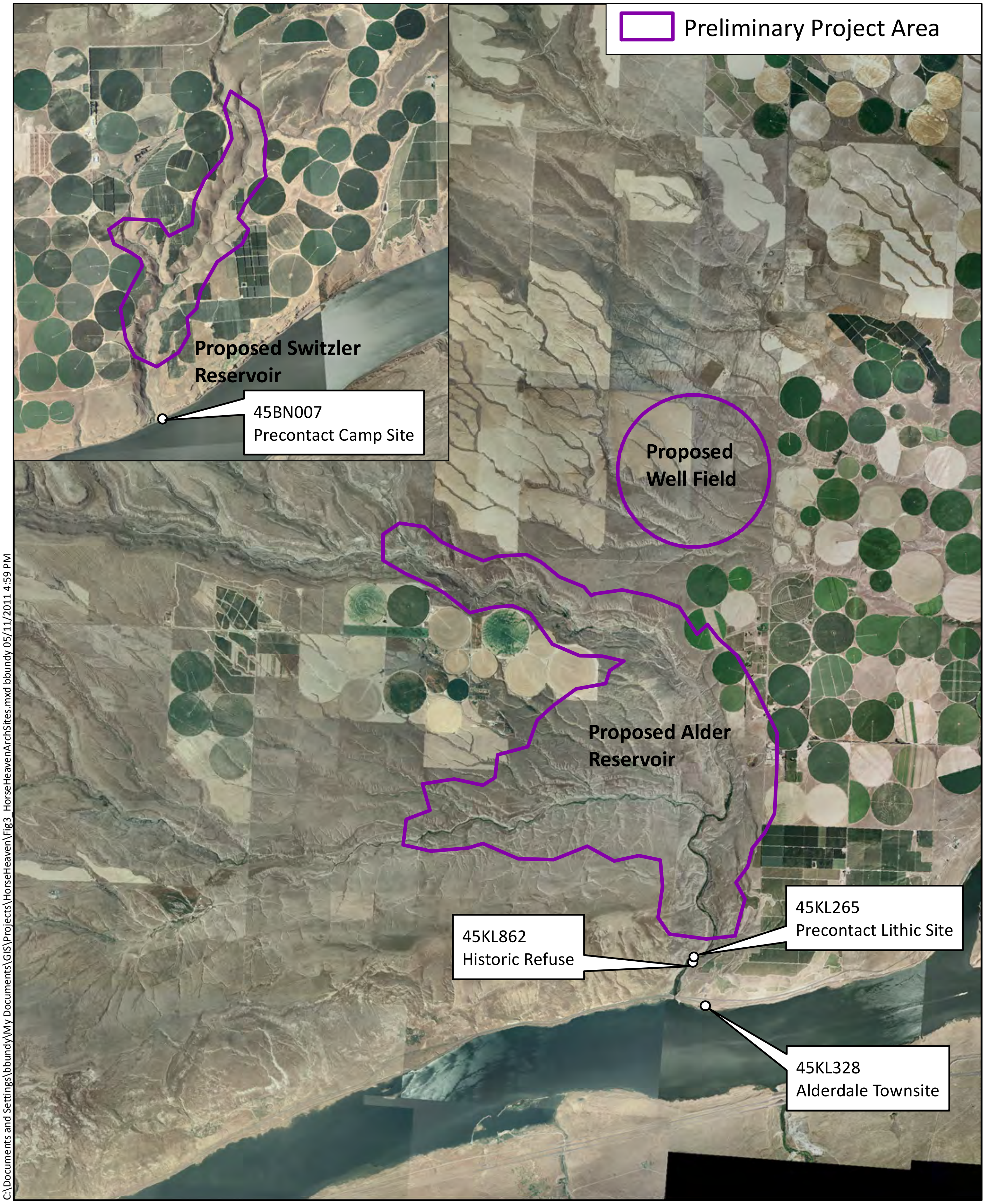

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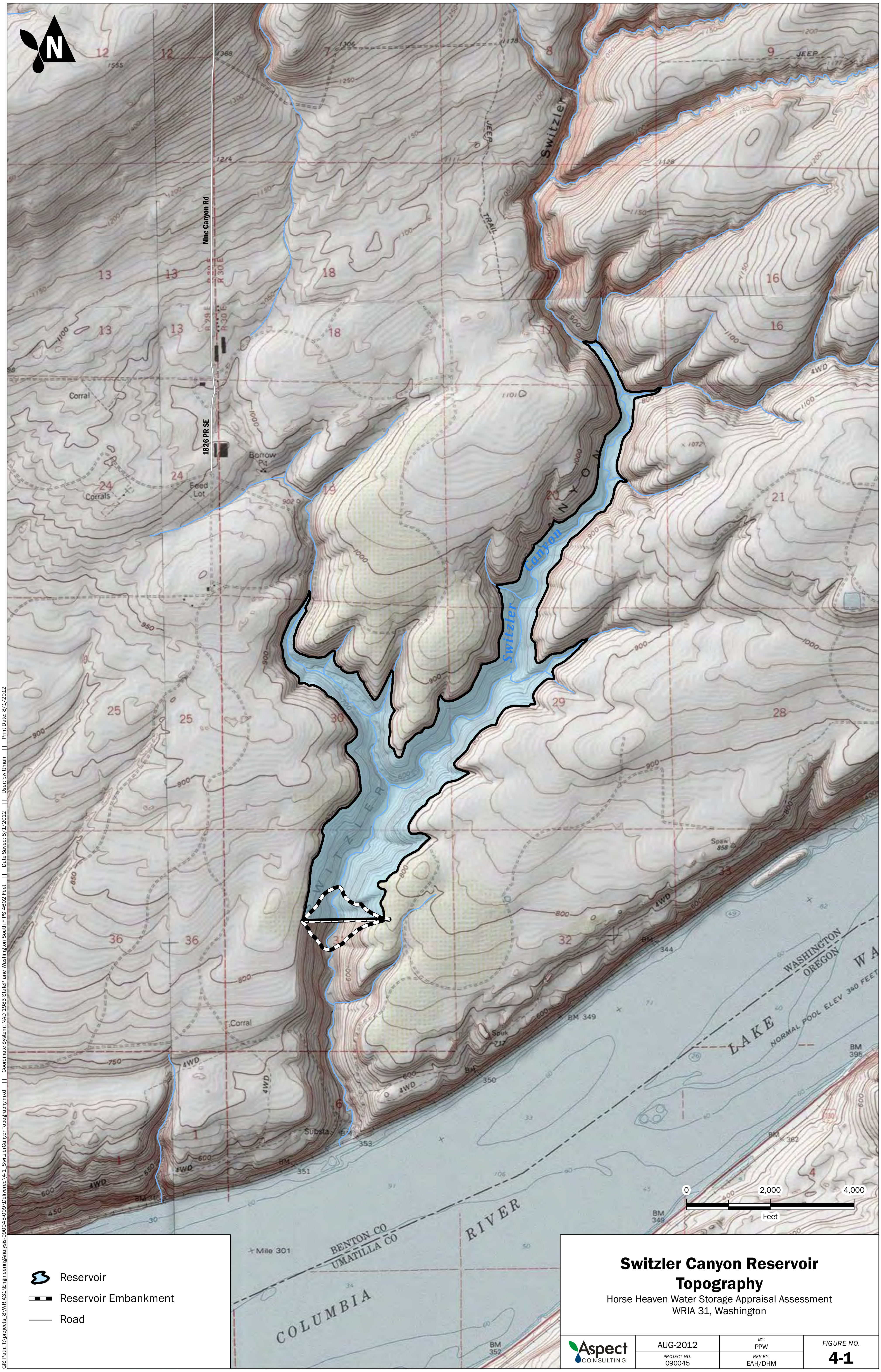
Figure 3-T

Archaeological Sites Within One Mile of Project Area
Archaeological Assessment
Horse Heaven Water Storage Appraisal Assessment



Reservoir
Reservoir Embankment
Road

Switzler Canyon Reservoir Topography

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING

AUG-2012	BY: PPW	FIGURE NO.
PROJECT NO. 090045	REV BY: EAH/DHM	4-1

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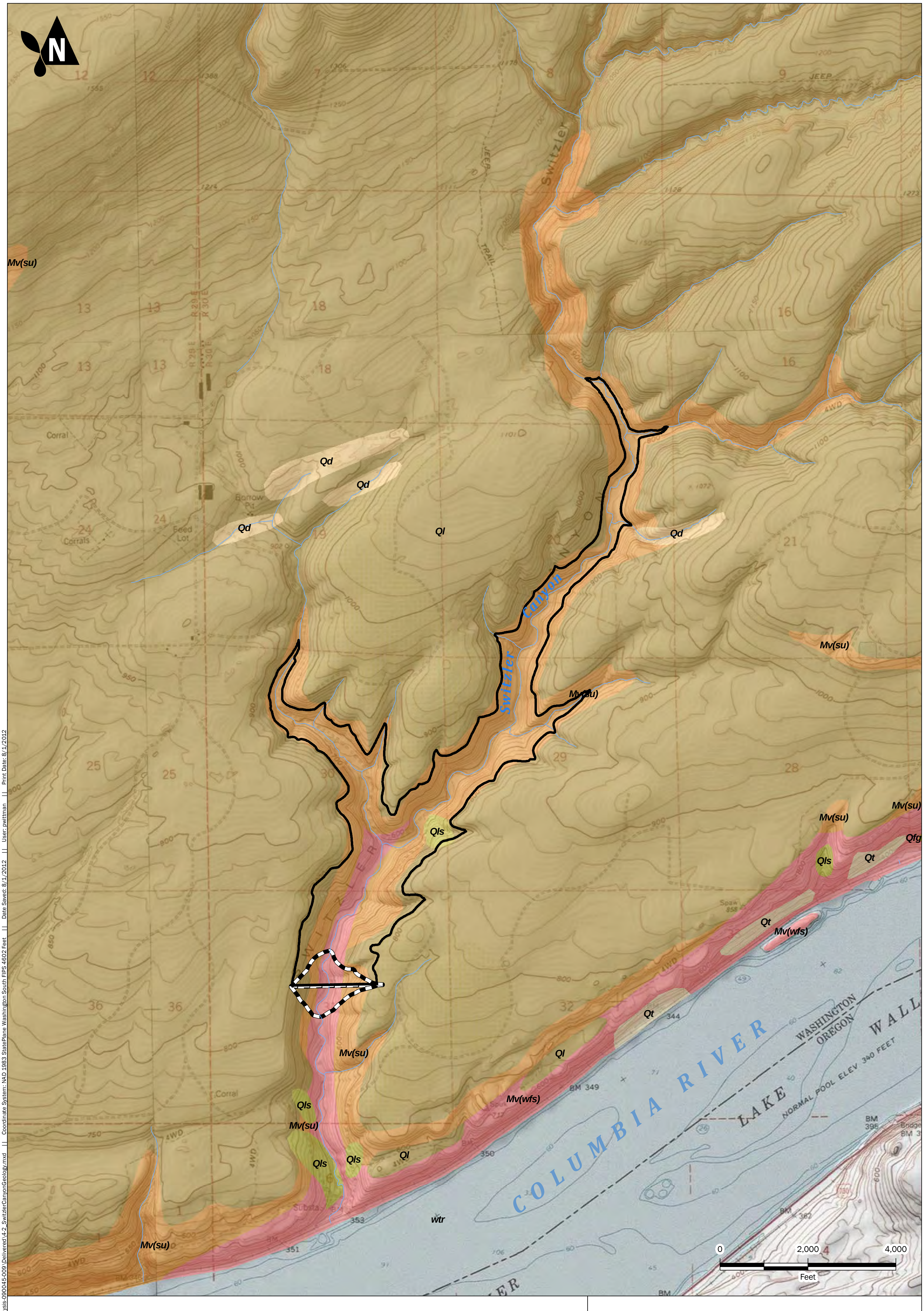

Reservoir

Reservoir Embankment

Surficial Geologic Units (WA DNR 1:100K)

- ▨ Mv(sp) - Pomona Basalt
- ▨ Mv(su) - Umatilla Basalt
- ▨ Mv(wfs) - Frenchmen Springs Basalt
- ▨ Qaf - Alluvial Fan Deposits
- ▨ Qd - Sand dune
- ▨ Qfg - Outburst Flood Deposts - Gravelly
- ▨ Ql - Loess
- ▨ Qls - Landslide Deposits
- ▨ Qt - Terraced Deposits

Switzler Canyon Reservoir Surface Geology

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	AUG-2012	BY: PPW	FIGURE NO.
	PROJECT NO. 090045	REV BY: EAH/DHM	4-2

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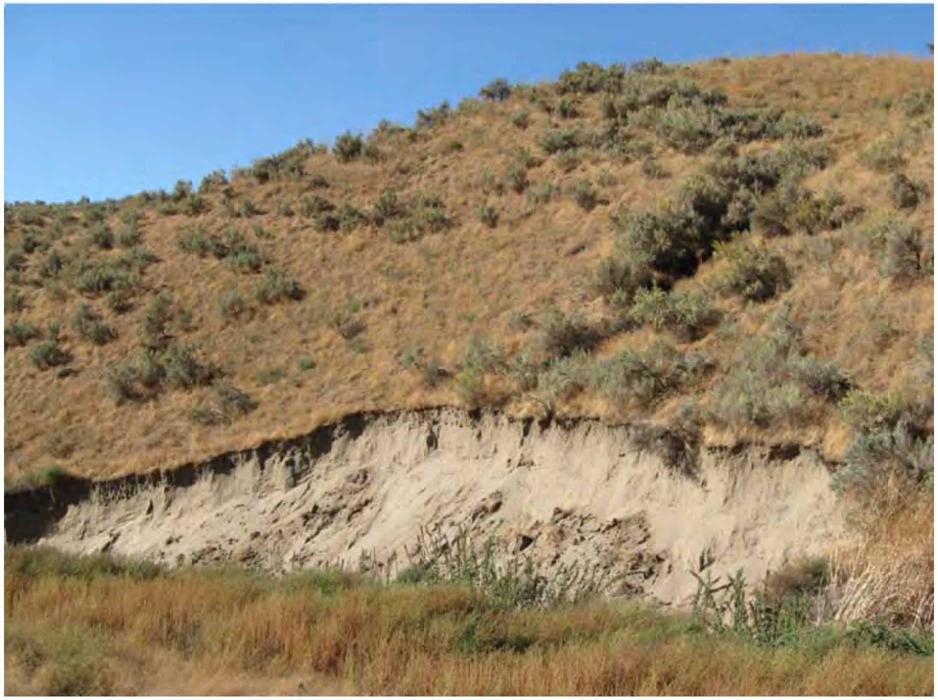


Slope failure caused by erosion along meandering creek.
Similar conditions can occur along reservoir shorelines.

Shallow slope failure triggered by erosion at toe of slope.
Similar failures may occur during reservoir filling and operation.

Switzler Canyon Reservoir
Shallow Slope Failures

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING	APR-2012	BY: DHM/SCC	FIGURE NO.
	PROJECT NO. 090045	REV BY: SCC	4-3

CAD Path: Q:\WRIA\090045 WRIA 31\2012-04 Horse Heaven Water Storage Assessment\090045-02.dwg Figure 4.1-Slope Failures L || Date Saved: Jul 31, 2012 4:54pm || User: scudd

══ Road

Ƹ Reservoir

▬ Reservoir Embankment

Source: Aerial image - USDA NAIP, 2011

Switzler Canyon Reservoir Land Use

Horse Heaven Water Storage Appraisal Assessment
WRIA 31, Washington

Aspect CONSULTING

AUG-2012

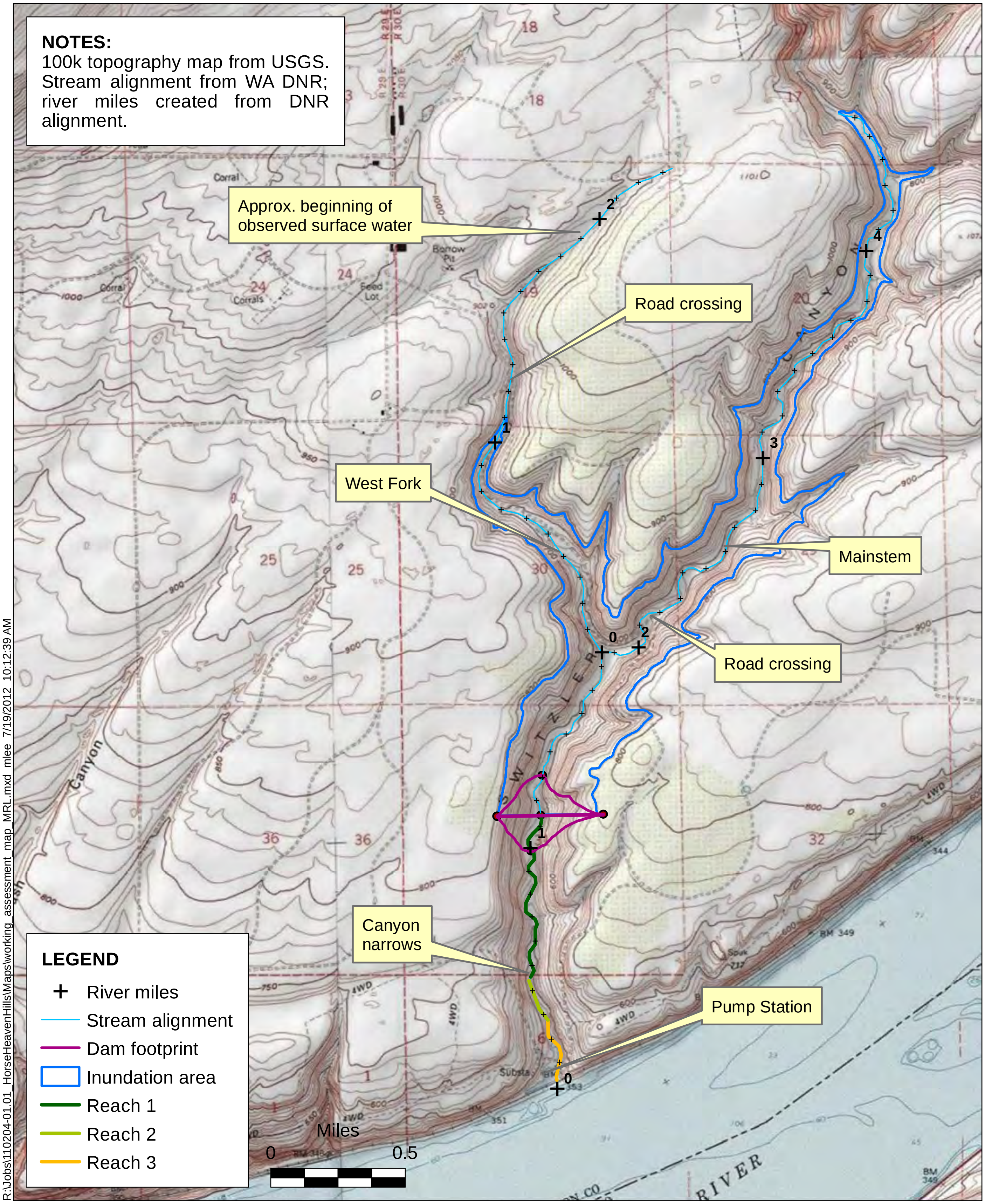
PROJECT NO.
090045

BY:
PPW

REV BY:
EAH/DHM

FIGURE NO.
4-4

GIS Path: T:\projects_8\WRIA31\EngineeringAnalysis-090045-009\Delivered\4-4_SwitzlerCanyonLandUse.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 8/1/2012 || User: pwittman || Print Date: 8/1/2012



NOTES:
100k topography map from USGS. Stream alignment from WA DNR; river miles created from DNR alignment.

Approx. beginning of observed surface water

Road crossing

West Fork

Mainstem

Road crossing

Canyon narrows

Pump Station

LEGEND

- + River miles
- Stream alignment
- Dam footprint
- Inundation area
- Reach 1
- Reach 2
- Reach 3

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Figure 4-5
Switzler Canyon Channel Geomorphic Reaches
Phase 1 Report
Horse Heaven Water Storage Appraisal Assessment

ANCHOR QEA

Note: Station SWZ10 location is approximate according to site descriptions.

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Figure 4-6

Stream Temperatures Recorded during Field Reconnaissance

Horse Heaven Water Storage Appraisal Assessment

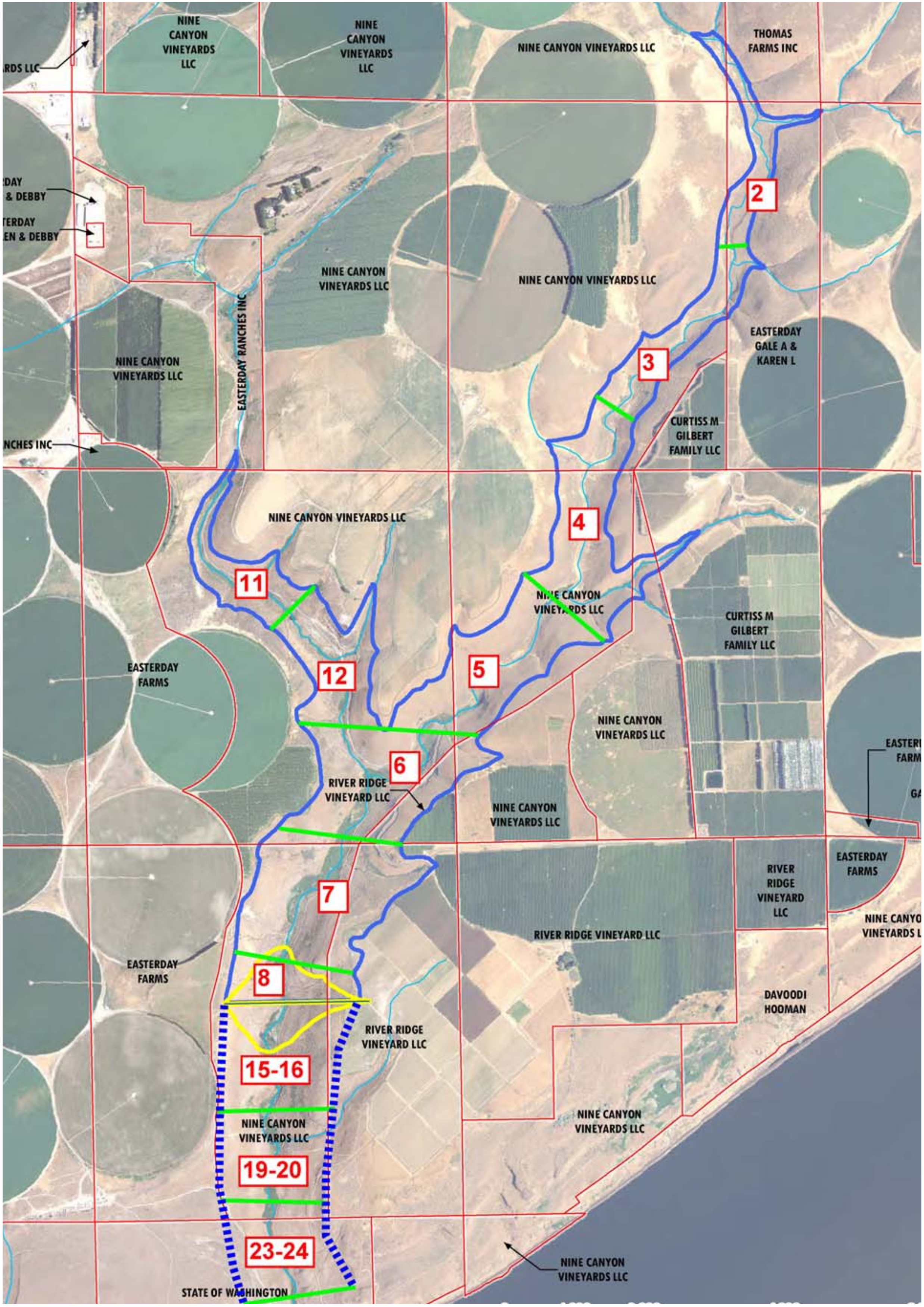
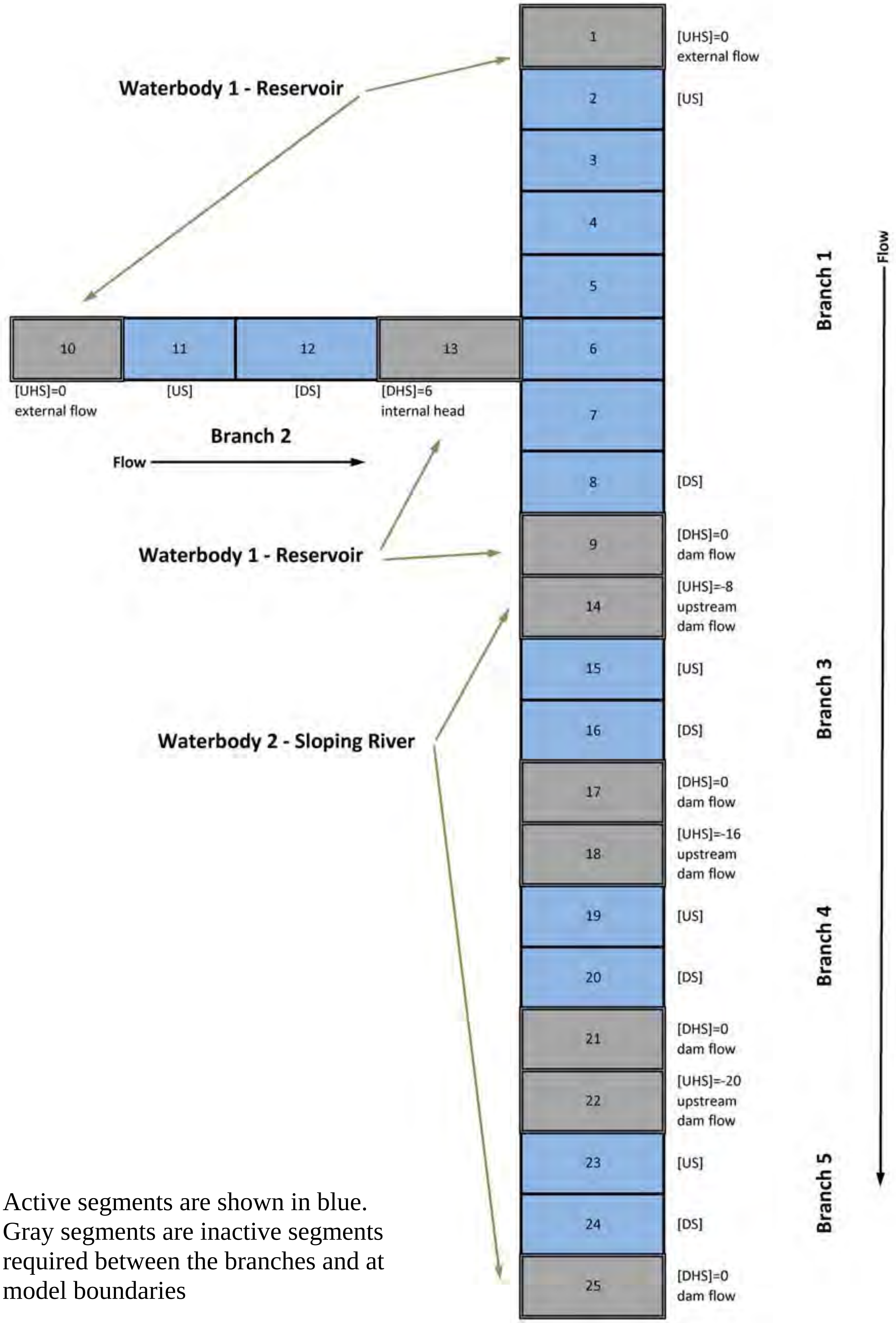


Figure 4-7
Reservoir Model Segmentation Map
Horse Heaven Water Storage Appraisal Assessment



Notes:
1. Active segments are shown in blue.
2. Gray segments are inactive segments required between the branches and at model boundaries

Figure 4-8
Reservoir Model Segmentation Schematic
Horse Heaven Water Storage Appraisal Assessment

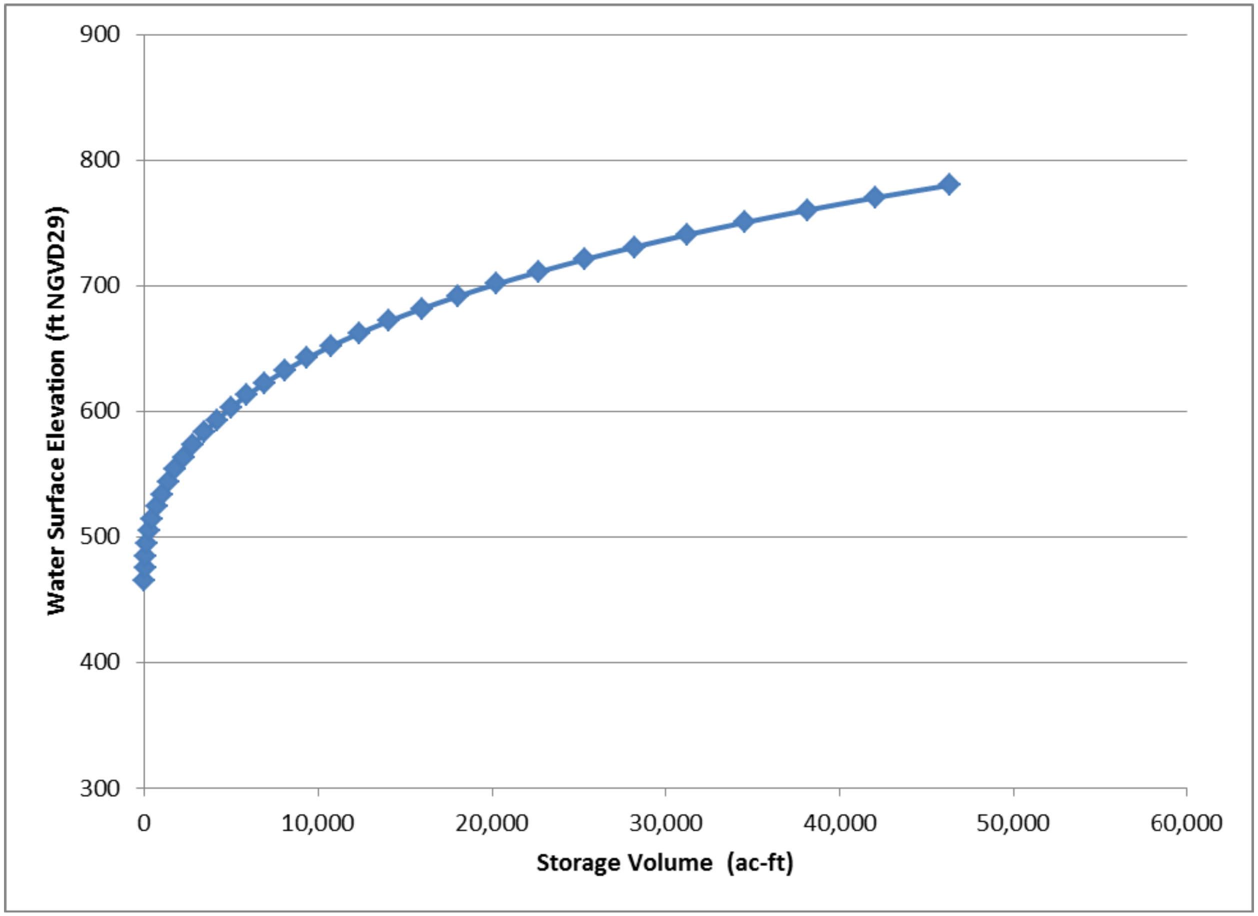
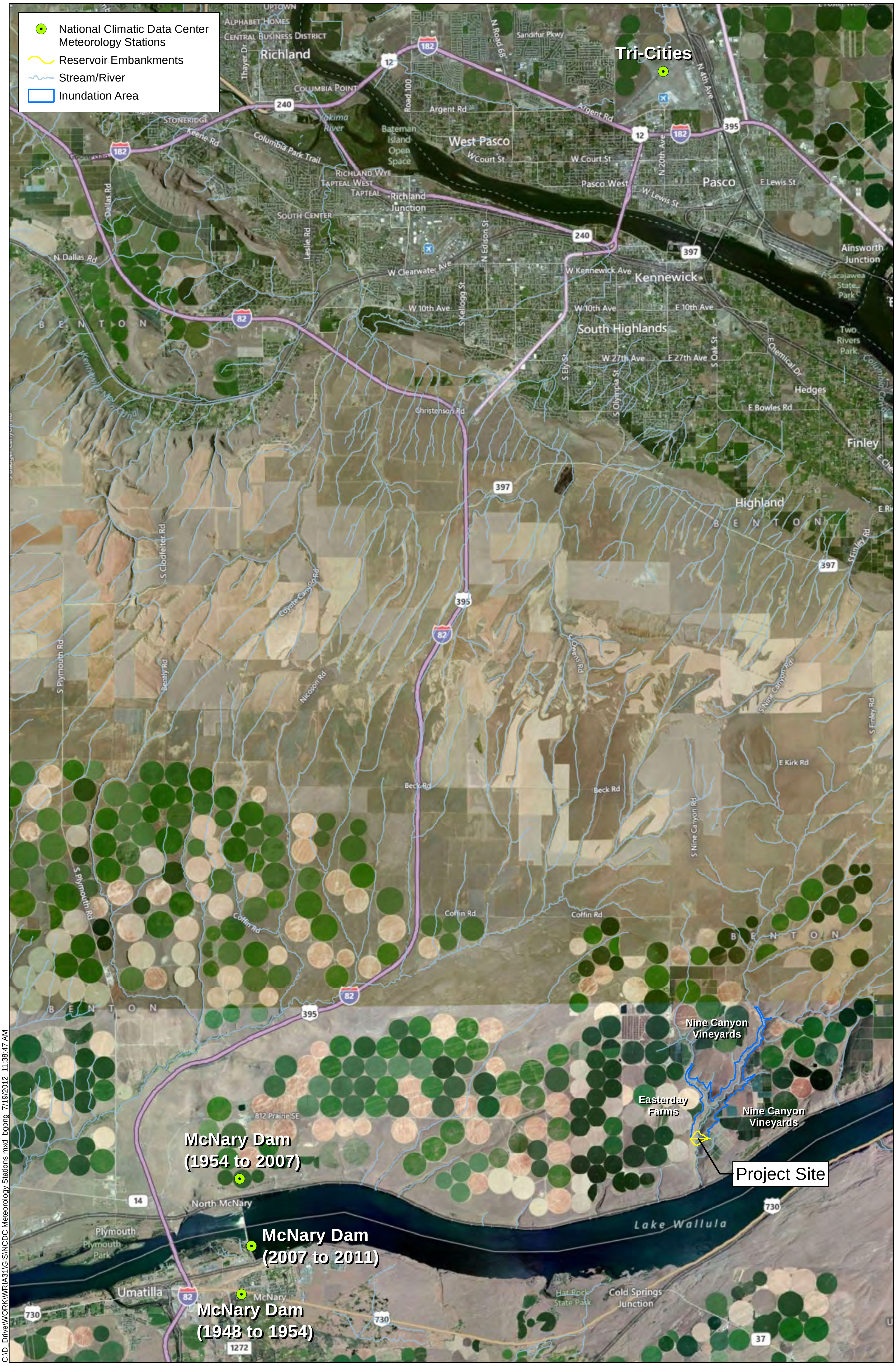


Figure 4-9
Elevation-Volume Relationship Represented in the CE-QUAL-W2 Model Grid
Horse Heaven Water Storage Appraisal Assessment



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ANCHOR QEA

Figure 4-10
National Climatic Data Center Meteorology Stations near Switzler Canyon
Horse Heaven Water Storage Appraisal Assessment

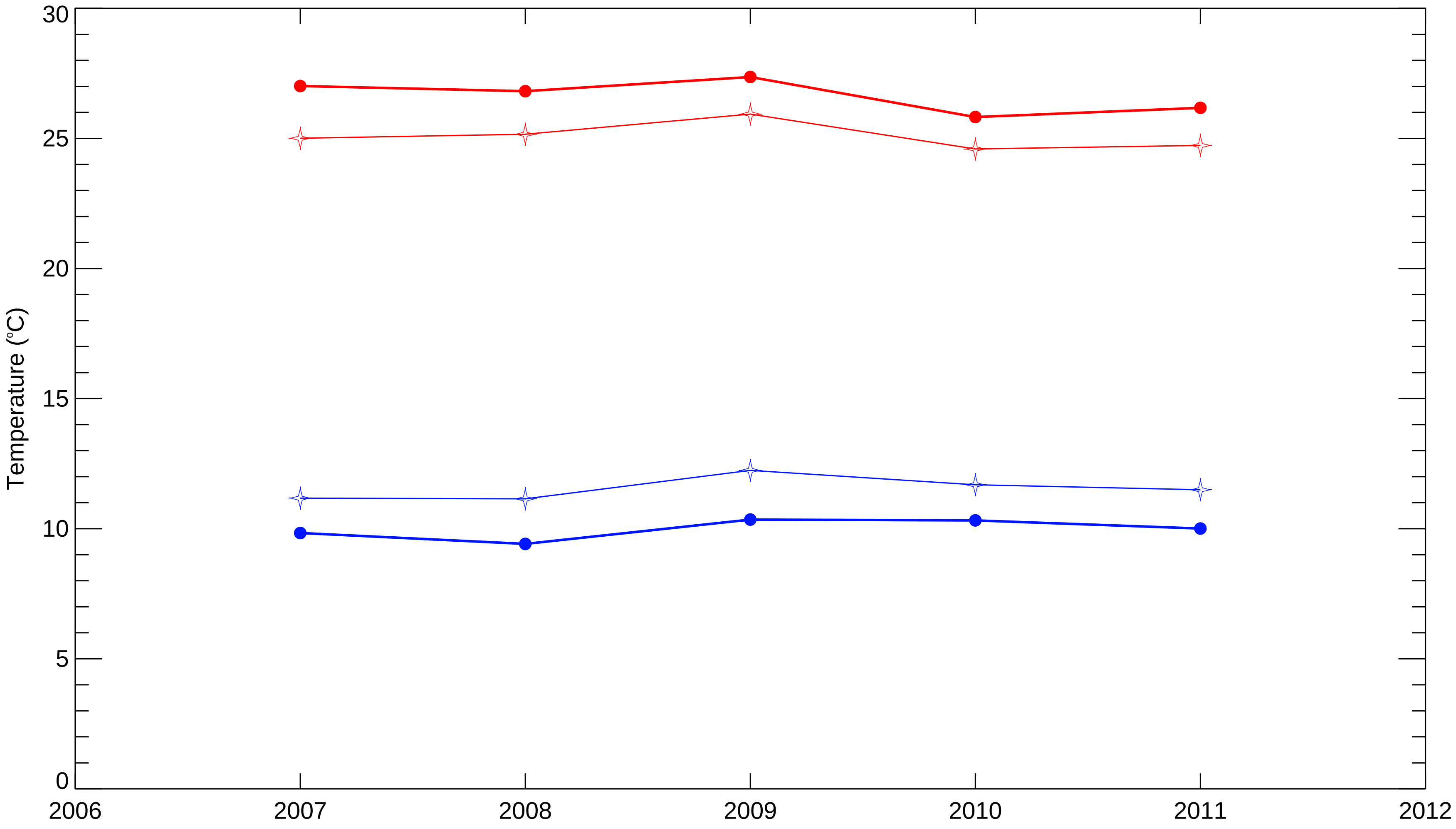

Figure 4-11

Comparison of Average Daily Range of Air Temperature Recorded at McNary Dam and Tri-Cities Stations

Horse Heaven Water Storage Appraisal Assessment

Model simulation period from 5/1 to 10/31

ANCHOR QEA

- ✧ Daily Max - McNary Dam
- ● Daily Max - Tri-Cities
- ✧ Daily Min - McNary Dam
- ● Daily Min - Tri-Cities

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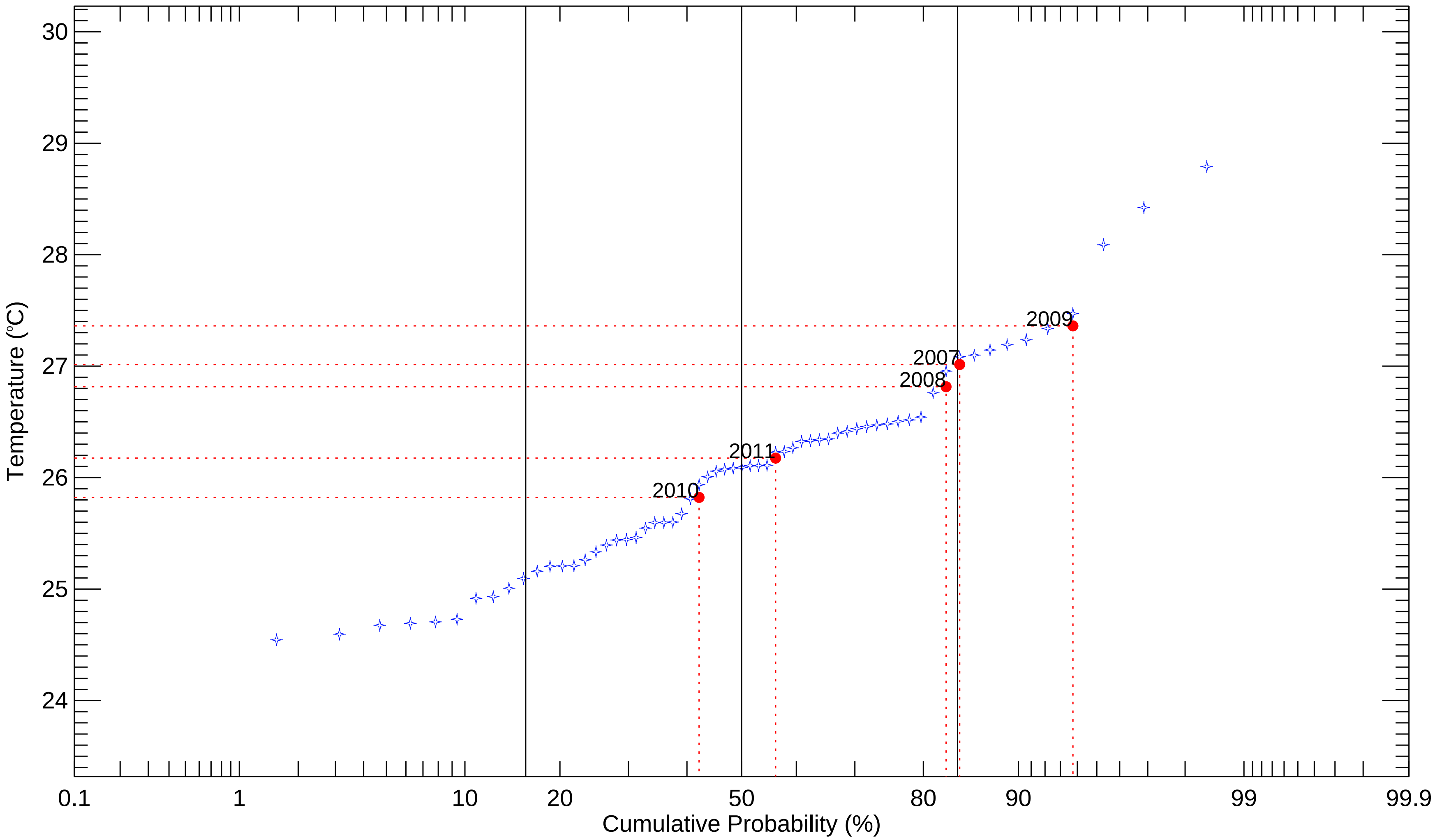

Figure 4-12

Probability Plots of the Average Daily Maximum Air Temperature at McNary Dam and Tri-Cities Stations
Horse Heaven Water Storage Appraisal Assessment

Model simulation period from 5/1 to 10/31

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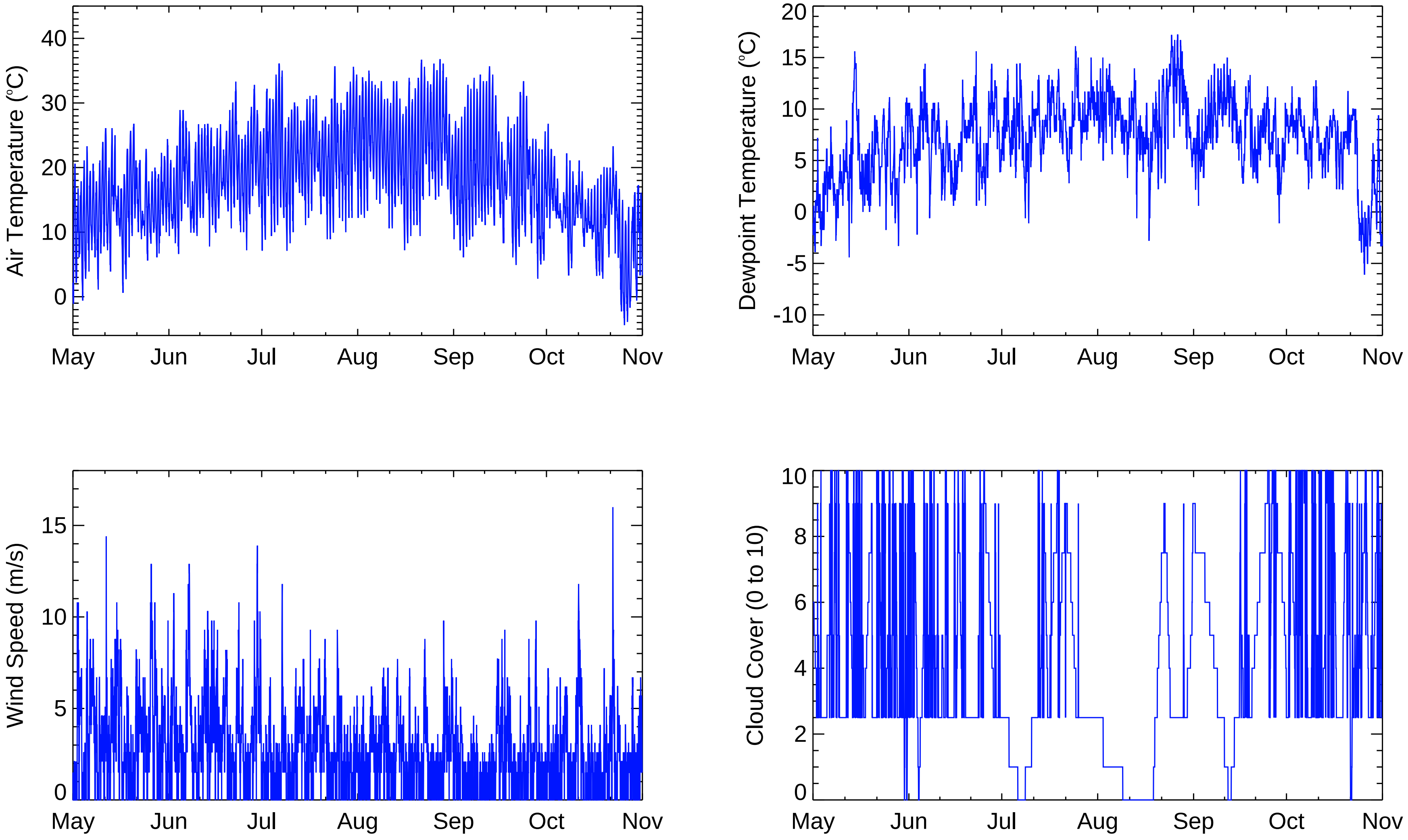

Figure 4-13a

Meteorological Forcing Functions Used for a Year with Moderate Air Temperature (2011)
Horse Heaven Water Storage Appraisal Assessment

Data from the Tri-Cites station

ANCHOR QEA

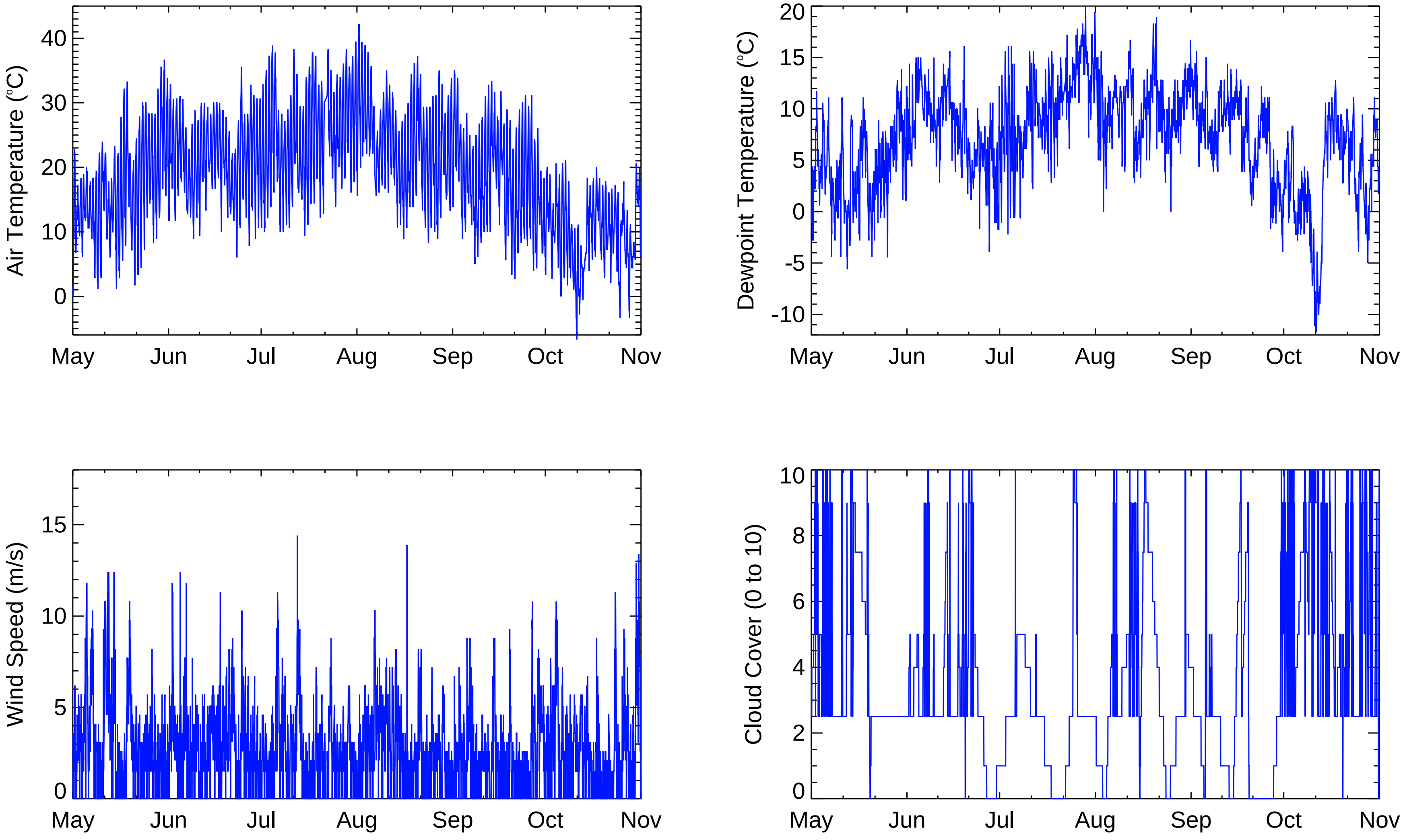

Figure 4-13b

Meteorological Forcing Functions Used for a Year with Warm Air Temperature (2009)
Horse Heaven Water Storage Appraisal Assessment
Data from the Tri-Cites station

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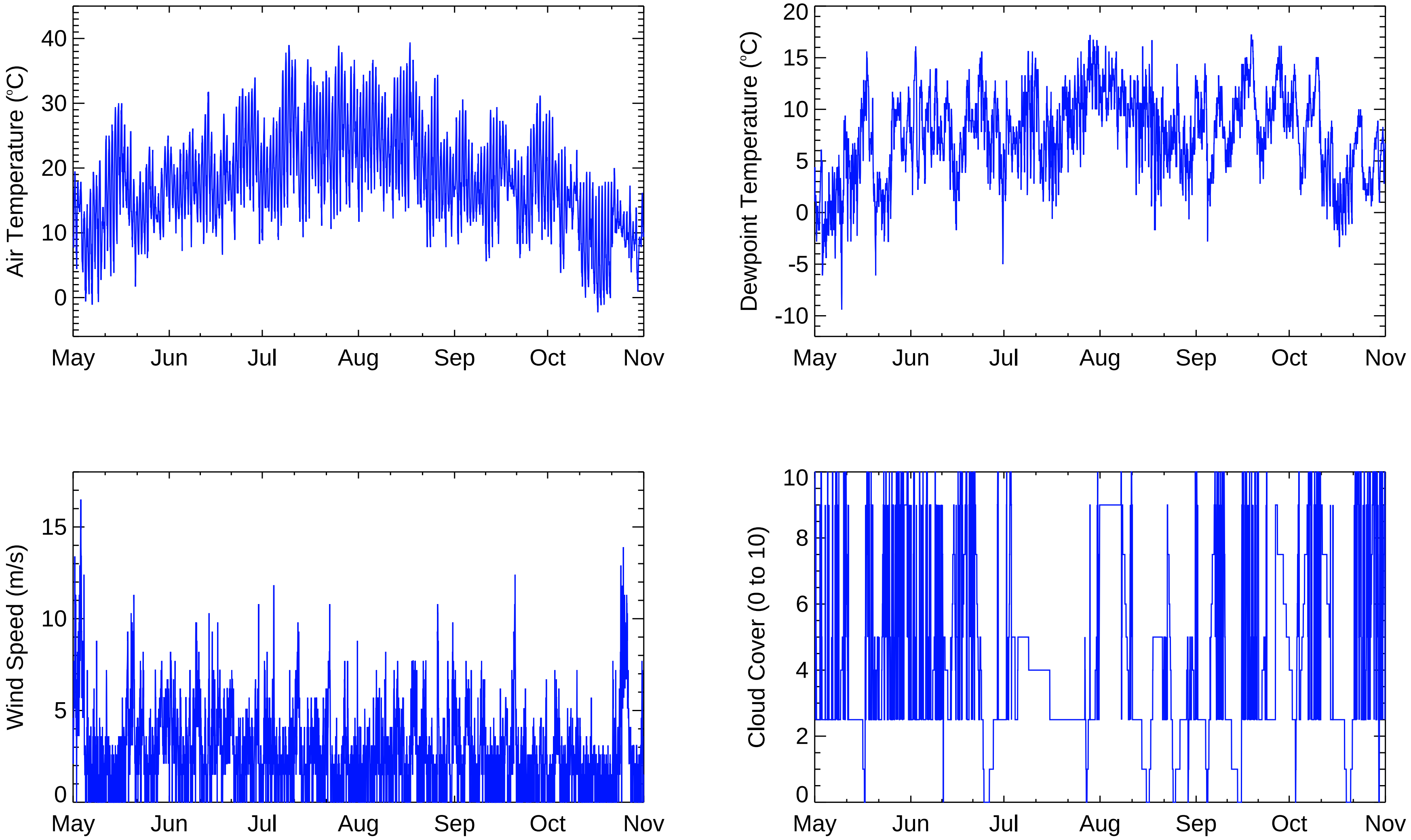

Figure 4-13c

Meteorological Forcing Functions Used for a Year with Cool Air Temperature (2010)
Horse Heaven Water Storage Appraisal Assessment

Data from the Tri-Cities station

ANCHOR QEA

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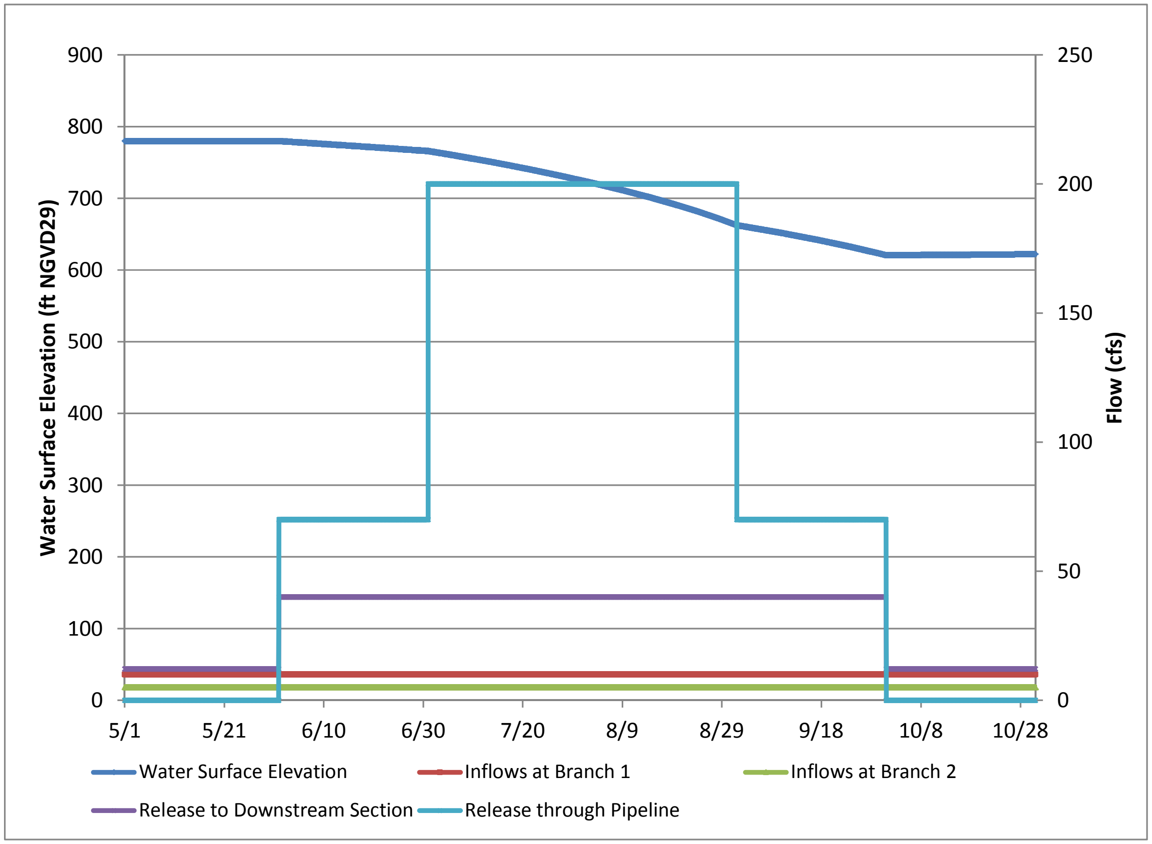
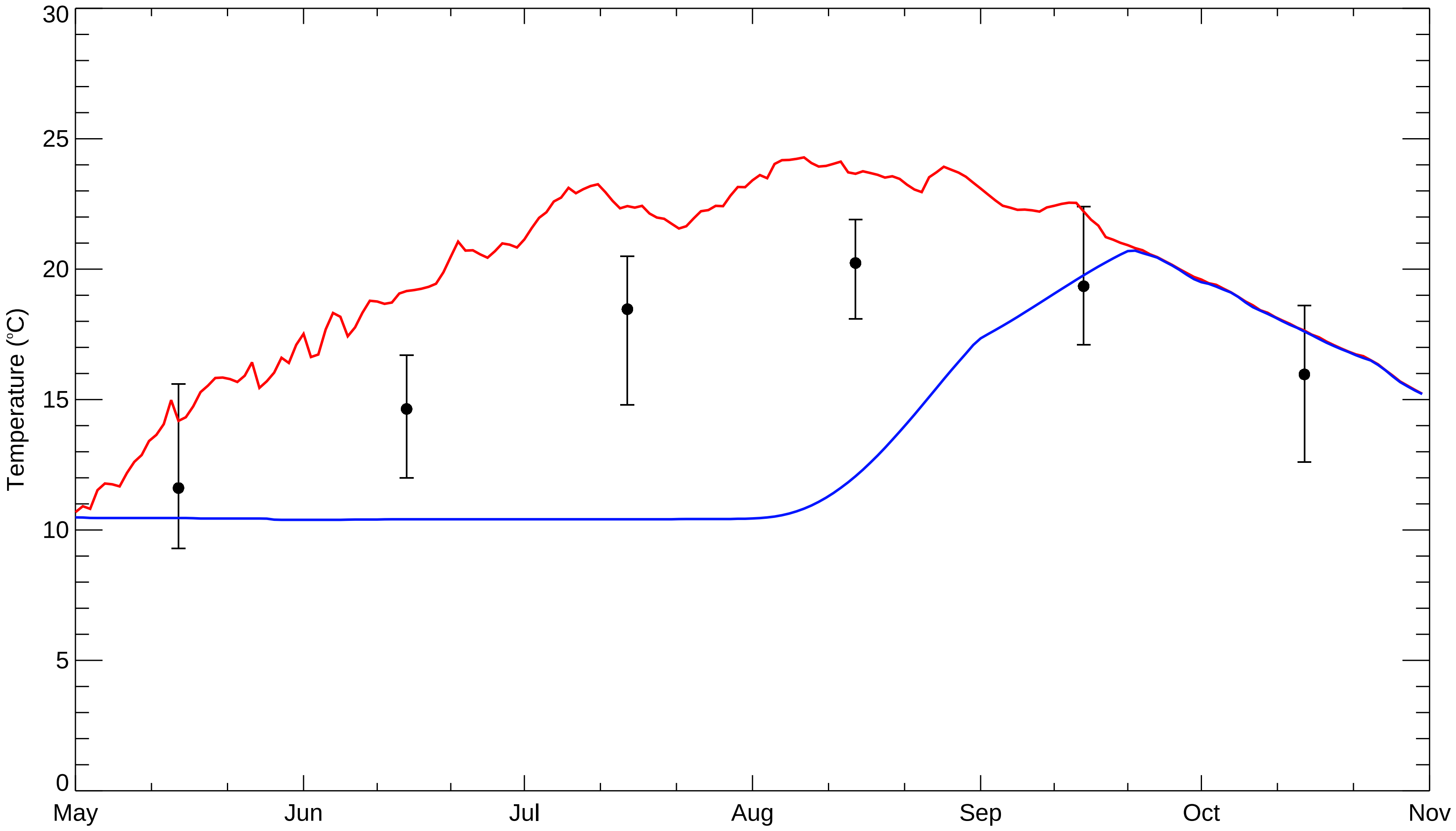


Figure 4-14

Changes in Water Surface Elevation at Segment 8 Resulting from Inflows and Outflows

Horse Heaven Water Storage Appraisal Assessment



ANCHOR QEA

Figure 4-15

Time Course of Simulated Surface and Bottom Water Temperature at Segment 8
Horse Heaven Water Storage Appraisal Assessment

Model results shown represent daily averages at the top 3 meters and bottom 3 meters of the water column
Data represents historical average and range in temperature measured at the WDOE Long-term Station 31A070

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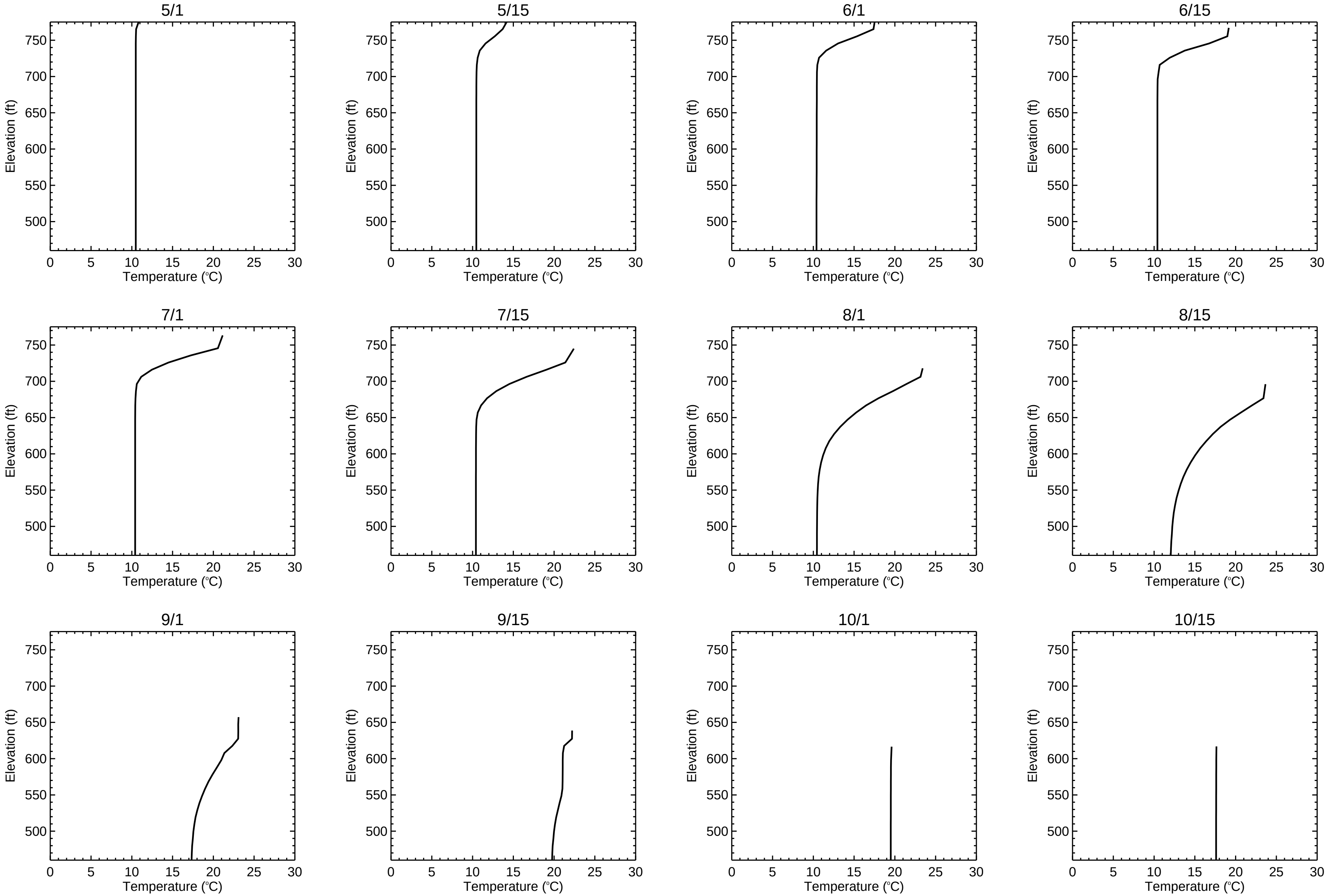

Figure 4-16

Depth Profiles of Simulated Water Temperature at Segment 8 for Moderate Year
Horse Heaven Water Storage Appraisal Assessment

Model results shown represent daily averages

ANCHOR QEA

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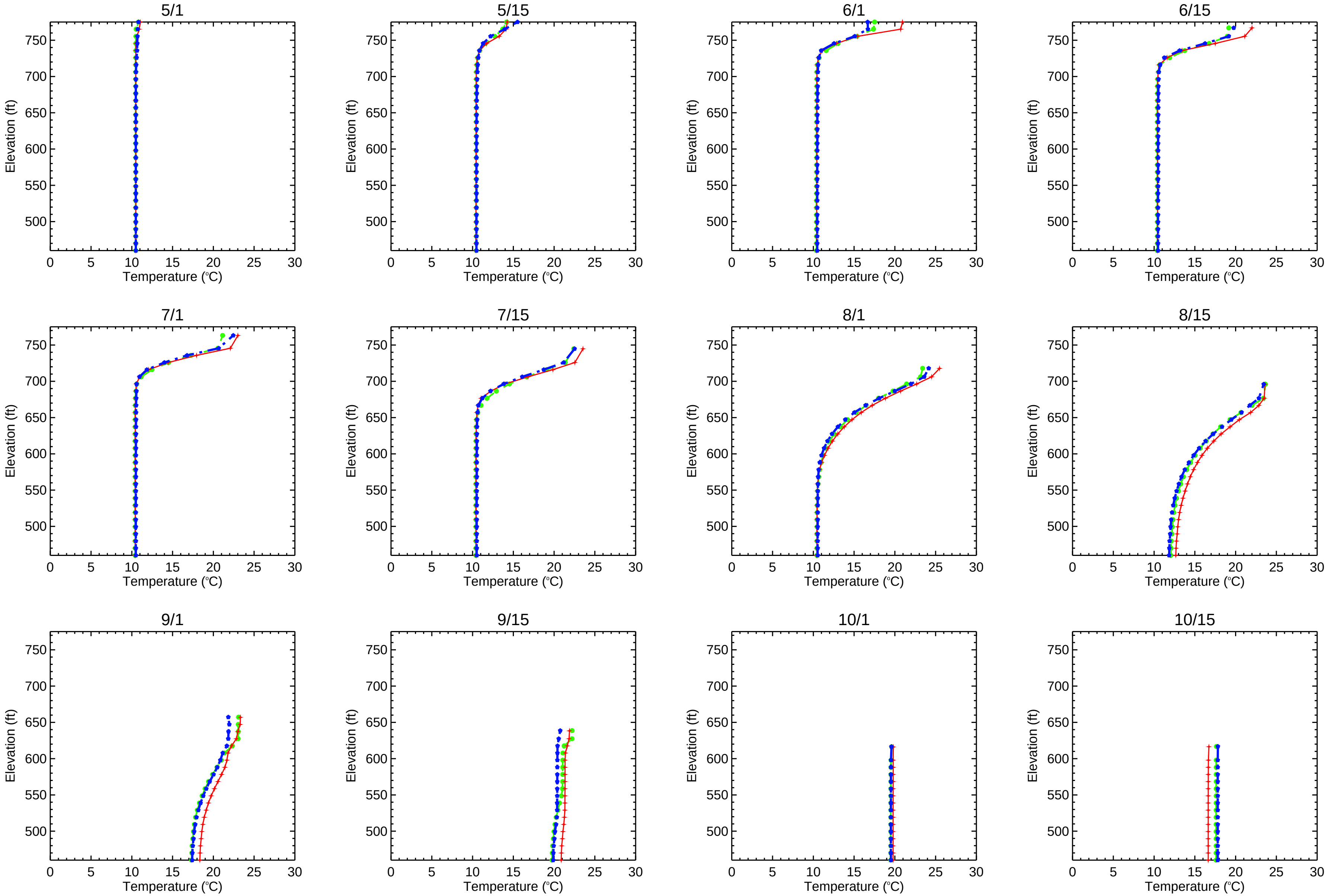

Figure 4-17

Depth Profiles of Simulated Water Temperature at Segment 8
Horse Heaven Water Storage Appraisal Assessment

Model results shown represent daily averages

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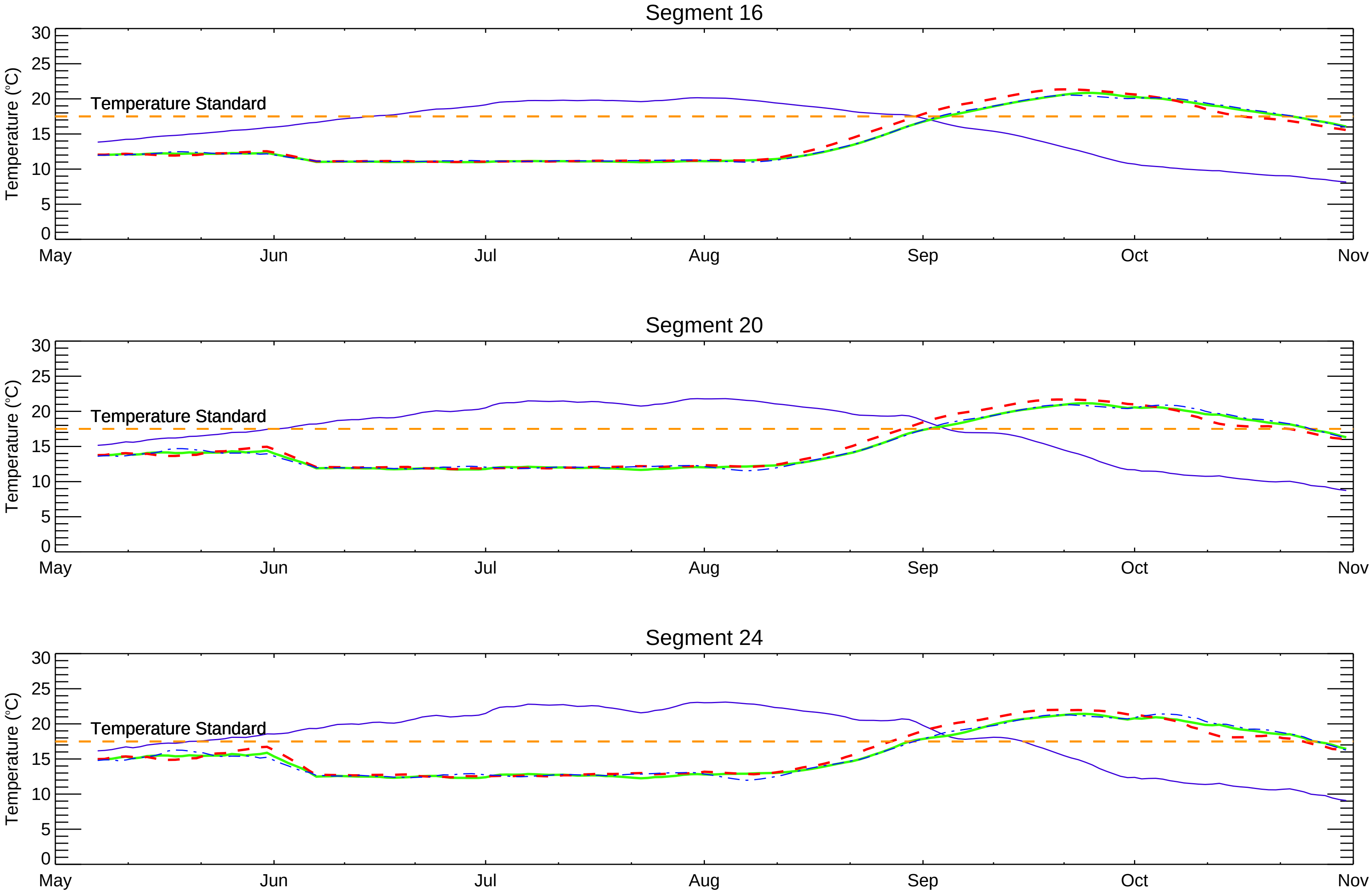

ANCHOR QEA

Figure 4-18

Time Course of 7-day Average of the Daily Maximum Temperature Simulated at the Downstream Segments
Horse Heaven Water Storage Appraisal Assessment

Model results shown represent daily maximums

APPENDIX A

Alder Creek Photographs from Geomorphology and Habitat Field Reconnaissance, September 2011

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photograph 5

Photograph 6

Photograph 7

APPENDIX B

Switzler Canyon Photographs from Geomorphology and Habitat Field Reconnaissance, September 2011

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photograph 5

Photograph 6

Photograph 7

Photograph 8

Photograph 9