SECTION B - Application Attachments

Instructions: Use this checklist to ensure required attachments are included with your application. All attachments to the application must be numbered as well as included in this list. For all attachments ensure documentation meets any criteria identified in the application instructions, Storage-Specific Guidance, and Guidance on Budget Procedures and Allowable Costs. For "other" optional attachments in excess of the three spaces provided, include a supplemental list.

Required Attachments:

- ☑ Attachment 1 – Site map (Question 3)
- ☑ Attachment 2 – Signed Landowner Agreement Forms (Question 5) to verify that you have authorized access to the lands on which the study would occur.
- ☑ Attachment 3 – Documentation of matching funds (Question 19) includes the following:
  - a) Match documentation for all match fund sources listed in the match fund table.
  - b) Match fund documentation that clearly identifies the dollar amount and describes the work to be accomplished with the match.
- ☑ Attachment 4 *(Select Storage Projects Only: if you answered "yes" to any part of Question 19)* – Description of approach to address storage-specific requirements; see the Storage-Specific Study Requirements: Application Guidance for the minimum requirements.

Optional Attachments:

- ☑ Letters of support (Question 12): Attachment #
- ☐ List and description of key tasks (Question 13): Attachment #
- ☐ Secured permits and regulatory approvals needed to implement the project (Question 15): Attachment #
- ☐ Other: Attachment #
- ☐ Other: Attachment #
- ☐ Other: Attachment #

All required items within Section A and B of the application checklist are completed and all identified criteria are addressed to the best of my knowledge.

Signature of Applicant/Authorized Person: [signature] Date: 11/13/2019

Print Name: Brian Wolcott Title: Executive Director, WWBWC

OREGON WATER RESOURCES DEPARTMENT

FEASIBILITY STUDY GRANTS

2019 GRANT APPLICATION

I. Study Information

Study Name: Pine Creek Reservoir Feasibility Study

Type of Feasibility Study: ☐ Water Conservation ☐ Reuse

x Storage (Above-Ground) ☐ Storage (Below-Ground)

Storage (Other)

Requested Grant Amount (must be no more than 50% of Total Study Cost): $ 105,976

Total Cost of Feasibility Study: $ 304,826

Note: Request(s) may not exceed $500,000 per project.

II. Applicant Information

Applicant Name: **Walla Walla Basin Watershed Council**		**Co-Applicant Name:**	
Address:	810 South Main Street	Address:	
	Milton-Freewater, OR 97862		
Phone:	541-938-2170	Phone:	
Fax:		Fax:	
Email:	brian.wolcott@wwbwc.org	Email:	

Principle Contact: same as above		**Fiscal Officer:** Chris Sheets	
Address:		Address:	same as above
Phone:	541-938-2170 ext 106	Phone:	541-938-2170 ext 101
Fax:		Fax:	
Email:	brian.wolcott@wwbwc.org	Email:	chris.sheets@wwbwc.org

Certification: I certify that this application is a true and accurate representation of the proposed work for a project feasibility study and that I am authorized to sign as the Applicant or Co-Applicant. By the following signature, the Applicant and Co-Applicant (if applicable) certifies that they are aware of the requirements of an Oregon Water Resources Department grant, have read and agree to all conditions within the sample Feasibility Study Grant Agreement and are prepared to conduct the study if awarded.

Signature of Applicant/Authorized Person: [signature] Date: 11/13/19

Print Name: Brian Wolcott Title: WWBWC Executive Director

Signature of Co-Applicant/Authorized Person: ______________________ Date: ________

2019 SOLICITATION

FEASIBILITY STUDY GRANTS

GRANT APPLICATION

APPLICATION DEADLINE: BY 5:00PM ON NOVEMBER 13, 2019

Application must be received by this date and time

Send application electronically to: WRD_DL_feasibilitystudygrants@oregon.gov

Mail application to:

OREGON WATER RESOURCES DEPARTMENT
Attention: Grant Program Coordinator
725 Summer Street NE, Suite A
Salem, OR 97301

APPLICATION SUBMISSION INSTRUCTIONS

1. **When completing your application, use the** Application Instructions available at the OWRD Funding Opportunities, Applications, Forms, and Guidance webpage: https://www.oregon.gov/OWRD/programs/FundingOpportunities/Pages/default.aspx

2. Complete all sections in the spaces provided. An application must be submitted on the attached form provided by the Department. An explanation must accompany the application if any of the information required cannot be provided [OAR 690-600-0020(6)].

3. Please ensure that the Certification portion of Section II is signed with a live signature by the Applicant and, if applicable, the Co-Applicant.

4. Taking part in a Pre-Application Conference prior to applying is ***highly*** recommended. The pre-application conference request form is available on the OWRD Funding Opportunities Forms webpage. To learn more contact the Department.

5. Complete and sign the application checklist.

6. Electronic submission of application is the preferred method. You may scan a copy of the signed signature page and submit with your application if both documents are included in the same email.

7. If application is submitted in hard copy - use 8 ½" x 11" single sided, unstapled pages. Provide any attachments to the application on 8 ½" x 11" single-sided, unstapled pages.

8. Contact the Department at 503.986.0869 or WRD_DL_feasibilitystudygrants@oregon.gov if you have any questions.

FEASIBILITY STUDY GRANT APPLICATION CHECKLIST

Instructions: Use this checklist to ensure that your application is complete. An incomplete application will not be eligible for further review and consideration. <u>This checklist must be completed and signed in order for your application to be considered complete.</u>

SECTION A - Application

I. Study Information
- ☒ Study name and type(s) is complete and correct.
- ☒ The requested grant amount and previous Feasibility Study Grants for the study do not exceed $500,000.
- ☒ The requested grant amount does not exceed 50% of the Total Cost of the Study.

II. Applicant Information
- ☒ All applicant and co-applicant name(s) and contact information is complete and correct.
- ☒ Application is signed by Applicant/Authorized Person.
- ☒ Application is signed by Co-Applicant/Authorized Person *OR* there is no co-applicant.

Note: *If the project is awarded funding the co-applicant will be required to sign and be party to the grant agreement.*

III. Study Location
- ☒ All questions have been addressed.
- ☒ Site plan map is attached.

IV. Feasibility Study Summary
- ☒ A brief (4-5 sentence) summary of the feasibility study and goal is included.

V. Feasibility Study Grant Specifics
- ☒ All questions have been addressed.
- ☒ Study key tasks are identified.

VI. Feasibility Study Budget
- ☒ All key tasks and budget items follow the Department's Budget Procedures and Allowable Costs guidance available on the OWRD Funding Opportunities Forms webpage.
- ☒ All budget information is accurate and complete.
- ☒ Administrative costs do not exceed 10% of total Grant Request.
- ☒ Key tasks listed in budget match those identified in Questions 13 and 14.

VII. Match Funding Information
- ☒ Matching Funds total, at a minimum, 50% of the Total Cost of the Feasibility Study.
- ☒ Match fund letters, indicating pending or secured match, are attached and equal the amounts listed in VI. Feasibility Study Budget.

VIII. Storage-Specific Questions
- ☒ All questions have been addressed *OR* the application is not for a storage project.
- ☒ Minimum Storage Specific Study Requirements are met and are incorporated into the study and key tasks.

SECTION B - Application Attachments

Instructions: Use this checklist to ensure required attachments are included with your application. All attachments to the application must be numbered as well as included in this list. For all attachments ensure documentation meets any criteria identified in the application instructions, Storage-Specific Guidance, and Guidance on Budget Procedures and Allowable Costs. For "other" optional attachments in excess of the three spaces provided, include a supplemental list.

Required Attachments:

☒ Attachment 1 – Site map (Question 3)

☒ Attachment 2 – Signed Landowner Agreement Forms (Question 5) to verify that you have authorized access to the lands on which the study would occur.

☒ Attachment 3 – Documentation of matching funds (Question 19) includes the following:

a) Match documentation for all match fund sources listed in the match fund table.

b) Match fund documentation that clearly identifies the dollar amount and describes the work to be accomplished with the match.

☒ Attachment 4 *(Select Storage Projects Only: if you answered "yes" to any part of Question 19)* – Description of approach to address storage-specific requirements; see the Storage-Specific Study Requirements: Application Guidance for the minimum requirements.

Optional Attachments:

☒ Letters of support (Question 12): Attachment #

☐ List and description of key tasks (Question 13): Attachment #

☐ Secured permits and regulatory approvals needed to implement the project (Question 15): Attachment #

☐ Other: Attachment #

☐ Other: Attachment #

☐ Other: Attachment #

All required items within Section A and B of the application checklist are completed and all identified criteria are addressed to the best of my knowledge.

Signature of Applicant/Authorized Person: ___see attached______________________ Date: _11/13/2019____

Print Name: Brian Wolcott_______________________ Title: __Executive Director, WWBWC

OREGON WATER RESOURCES DEPARTMENT

FEASIBILITY STUDY GRANTS

2019 GRANT APPLICATION

I. Study Information

Study Name: Pine Creek Reservoir Feasibility Study

Type of Feasibility Study: ☐ Water Conservation ☐ Reuse

x Storage (Above-Ground) ☐ Storage (Below-Ground)

Storage (Other)

Requested Grant Amount (must be no more than 50% of Total Study Cost): $ 105,976

Total Cost of Feasibility Study: $ 304,826

Note: Request(s) may not exceed $500,000 per project.

II. Applicant Information

Applicant Name: Walla Walla Basin Watershed Council		**Co-Applicant Name:**	
Address:	810 South Main Street	Address:	
	Milton-Freewater, OR 97862		
Phone:	541-938-2170	Phone:	
Fax:		Fax:	
Email:	brian.wolcott@wwbwc.org	Email:	

Principle Contact: same as above		**Fiscal Officer:** Chris Sheets	
Address:		Address:	same as above
Phone:	541-938-2170 ext 106	Phone:	541-938-2170 ext 101
Fax:		Fax:	
Email:	brian.wolcott@wwbwc.org	Email:	chris.sheets@wwbwc.org

Certification: I certify that this application is a true and accurate representation of the proposed work for a project feasibility study and that I am authorized to sign as the Applicant or Co-Applicant. By the following signature, the Applicant and Co-Applicant (if applicable) certifies that they are aware of the requirements of an Oregon Water Resources Department grant, have read and agree to all conditions within the sample Feasibility Study Grant Agreement and are prepared to conduct the study if awarded.

Signature of Applicant/Authorized Person: see attachment Date: ________

Print Name: Brian Wolcott Title: WWBWC Executive Director

Signature of Co-Applicant/Authorized Person: ________________ Date: ________

Print Name: _________________ Title: _________________________________

III. Feasibility Study Summary

1. Please provide a brief, 4-5 sentence summary of the feasibility study. This summary should include a brief description of the goal of the water conservation, reuse, or storage project being studied and the purpose of the study. Please refer to the Feasibility Study Grant Application Instructions for additional information on what to include in your study summary.

The Pine Creek Reservoir storage feasibility study funding will include the following work needed to evaluate the feasibility of the reservoir site; complete geotechnical investigations, seismic analysis, further analysis of Walla Walla River water availability, and Pine Creek geomorphology, biology, and hydrology analyses necessary to complete the Oregon storage-specific study requirements for the Pine Creek water availability assessment. The goal is to determine if this Pine Creek Reservoir site in Umatilla County on an intermittent stream can store a portion of the abundant winter and early spring flows of both the Walla Walla River and Pine Creek in order to provide an alternative source of irrigation water to Walla Walla valley irrigation districts. The irrigation districts would then leave a corresponding amount of their existing irrigation water rights instream during late spring, summer, and the fall when limited Walla Walla River stream flows impact fish passage, rearing habitat, and water quality for federally pprotected ESA listed steelhead and bull trout, and for chinook salmon reintroduced to the Walla Walla River by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). This Pine Creek Reservoir project has been identified as a priority project to be investigated by the ongoing Walla Walla Basin Integrated Flow Enhancement Study. This OWRD proposal matched with WDOE funds and a proposal to the U.S. Bureau of Reclamation will provide key answers regarding the feasibility of this reservoir site.

IV. Study Location

Instructions: Please answer the following questions about the location of the feasibility study and project being evaluated.

2. Please provide the following information about the study and project location.
   a. Latitude/Longitude (in decimal degrees): 45.950970/ -118.530496
   b. County: Umatilla
   c. Watershed/Basin (HUC 10 number): Walla Walla/1707010207

3. Please attach a site plan map showing the following and label as Attachment #1:
   a. Feasibility study area boundaries
   b. Project area (if implemented)
   c. True north arrow
   d. Map title and legend
   e. Latitude and longitude
   f. Property boundaries
   g. Surface water bodies
   h. Sampling locations (if proposed)
   i. Points of Diversion and Place of Use, labeled for each water right (if applicable)

4. Check the box which best describes the properties involved in the proposed <u>Feasibility Study</u>.
   a. ☐This Feasibility Study will not impact or access lands.

b. ☒This Feasibility Study will impact or access lands. Complete the table below to identify any properties where access is required for the feasibility study or on which the study would occur. *Add rows as needed.*

Tax Map Number	Tax Lot Number	Ownership Type (✓ One)	Property Owner of Record
6N34000004400	6N34000004400	☐Public ☒Private	Adolf Klein
		☐Public ☐Private	
		☐Public ☐Private	
		☐Public ☐Private	
		☐Public ☐Private	

5. Attach a signed Landowner Agreement form for each property listed in Question #4 where access to the property is required or on which the Feasibility Study would occur. Attach Landowner Agreement form(s) only for those properties involved in the Feasibility Study and label Attachment #2. (Landowner Agreement forms may be found on the Applications, Forms and Guidance webpage.)
   a. Where a single landowner entity is the owner of record for multiple properties, one form may list the multiple properties owned by that entity.

   b. For *public* lands attach the landowner form or other documented authorization from the federal or state government property owner allowing the feasibility study activities **or** documentation that demonstrates such authorization is being pursued.

6. Check the box which best describes the properties involved in future project Implementation. Identify any lands that would be impacted or accessed during future project implementation. Check all that apply and provide the requested information.
   a. ☐The proposed project, if implemented, will only impact or access lands already identified in Question 4 (must have selected box b under question 4).

   b. ☐The proposed project, if implemented, will likely impact or access lands during implementation, but those lands likely to be accessed or impacted have not been identified, OR this question is not applicable. If this box (6b) is checked, do not complete the table below.

   c. ☒The proposed project, if implemented, is highly likely to impact or access additional lands during implementation. If this box (6c) is checked, complete the table below to identify any additional properties (those not already identified under question (4)) where access is required for future project implementation. *Add rows as needed. No Landowner Agreement forms are required for lands listed only under this question.*

Tax Map Number	Tax Lot Number	Ownership Type (✓ One)	Property Owner of Record
		☐Public ☒Private	Randal Kessler
		☐Public ☒Private	Patrick Kelly
		☐Public ☐Private	
		☐Public ☐Private	
		☐Public ☐Private	

V. Feasibility Study Specifics

Instructions: Please answer all questions in this section. As applications are expected to result in additional pages to complete this section, you may attach your responses on a separate document as long as you indicate the question numbers in your response.

Study Description, Needs, and Goals

7. Describe the feasibility study goal.

The goal of this Pine Creek Reservoir feasibility study is to determine the following aspects of feasibility: seismic, geologic, availability of source materials for dam construction, Walla Walla River water availability, and Pine Creek water availability assessment and Oregon's storage-specific study requirements, costs, and ability to meet numerical flow restoration targets at eight selected management points. The goal of constructing a approximately 28,000 acre-feet reservoir is to re-time surface water supplies, by storing the higher winter and early spring flows in the Walla Walla River and Pine Creek so they are available in late spring, summer and fall when water for irrigation and fish is scarce. The Walla Walla River and its tributaries provide for agricultural production, support thriving communities, and sustain resident and anadromous fish populations. The Walla Walla River flows from its headwaters in Oregon to its confluence with the Columbia River in Washington. As in many western river basins, water supplies in the Walla Walla Basin are over-appropriated. This feasibility study will determine the suitability of an off-channel Pine Creek Reservoir as an alternative water source for irrigation districts in order for a corresponding amount of their water rights to remain instream for fish.

The Pine Creek Reservoir alternative has been identified as one of two large water supply, or anchor projects, in the *Walla Walla Basin Integrated Flow Enhancement Study Report, 2017.* Seismic and geological information needed includes a site-specific fault study (drilling deep boreholes through the overlying alluvium into the basalt formation layers with *in situ* testing, televiewer logging, and packer testing at 5-6 sites along the proposed dam location), a borrow material source evaluation, and a conceptual design for an earth-core rockfill dam. The previously completed desktop geologic study indicated that a splay fault from the Wallula Fault System likely extends through the proposed dam foundation. In and of itself, this is not a fatal flaw. The site-specific fault study will determine the location, the sense of slip direction, and the potential rupture height and length of the Pine Creek fault trace. Obtaining data on these parameters will characterize the likelihood and magnitude of future slippage and thus whether the site is geologically unsuitable. The borrow material source evaluation will determine if there is suitable borrow material near the reservoir site and if it will be economically feasible to construct the dam core. If the site-specific fault study and the borrow material source evaluation do not identify a fatal flaw with the Pine Creek Reservoir alternative, then a new conceptual design for an earth-core rockfill dam will be completed for the site. The conceptual design of the dam will include the approximate material volume needed; this volume will be compared to the approximate volume of suitable borrow source material identified. The conceptual design will also include cost estimates for construction and annual operations and maintenance for the new dam.

The need for this Pine Creek Reservoir is to increase stream flows in the Walla Walla River in late spring, summer, and fall months when federally protected ESA- listed steelhead and bull trout, and spring chinook salmon reintroduced by the CTUIR are present. This project will restore streamflows for ESA listed aquatic species, culturally significant species, and ecological functions, while at the same time not impacting water needed to sustain irrigated agriculture, residential use, and municipalities in the Walla Walla River basin. To increase stream flows to meet the target flows requires 35,000 acre-feet of water. The higher stream flows in the Walla Walla River would be almost achieved by replacing 28,000 acre feet of water diverted from the Walla Walla River in the late spring, summer, and fall months with winter and early spring runoff water that has been stored in the Pine Creek Reservoir. The shortfall of 7,000 acre-feet would be met by implementing other water projects. The 35,000 acre feet would double and triple the existing base flows measured each summer in the middle and lower reaches of the Walla Walla River. A portion of the high winter and early spring flows would be diverted from the Walla Walla River and piped using gravity in to the proposed Pine Creek Reservoir.

The goal of the this Pine Creek Reservoir alternative feasibility and data analysis is to complete the necessary geotechnical investigations, refine the Walla Walla water availabilty assessment based on current data and OWRD guidance, and a Pine Creek water availability assessment and storage-specific study requirements, to determine the feasibility, costs, ability to meet flow targets, and to inform the conceptual design for an earth-core rockfill dam. The overarching goal of this project is to make the higher Walla Walla River and Pine Creek stream flows in winter and early spring storable so they are available in late spring, summer and fall when water for irrigation and fish is scarce. This study will explore the feasibility of an off-channel water storage reservoir (located in the Pine Creek drainage, an intermittent tributary of the Walla Walla River).

8. Describe how the proposed study would achieve the goal.

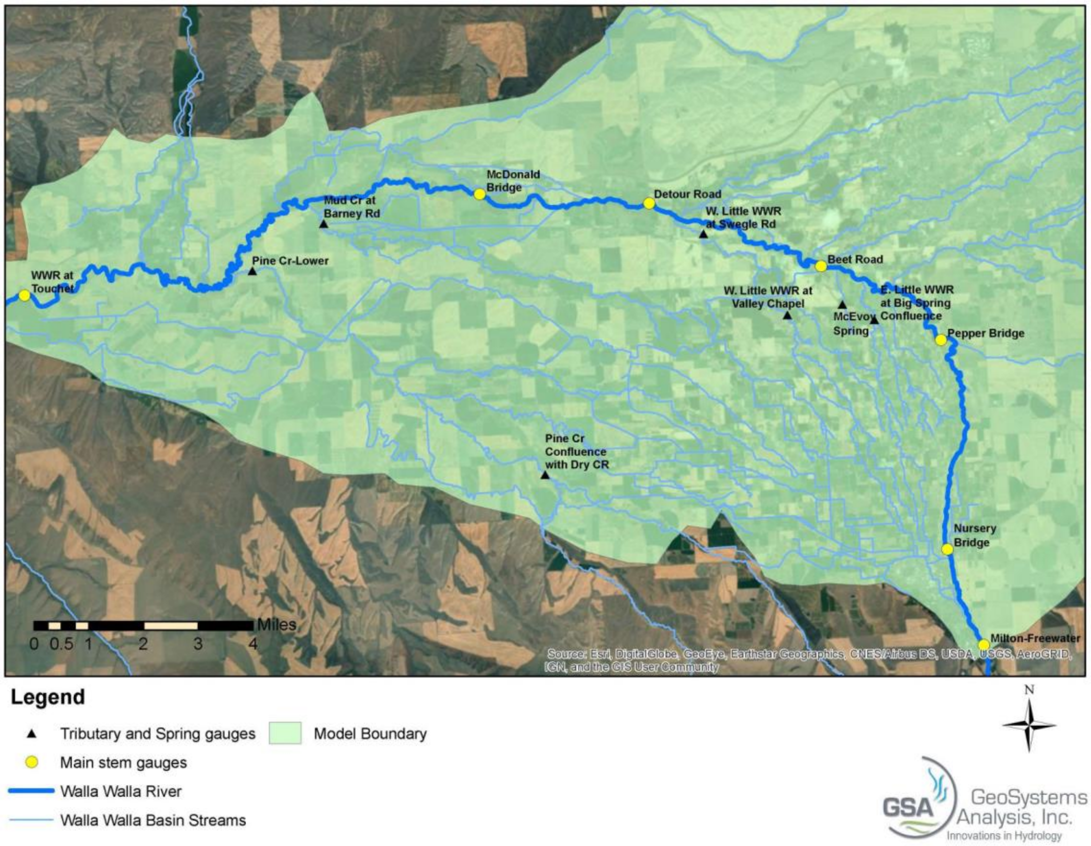
This feasibility study will build upon information in the *Walla Walla Basin Integrated Flow Enhancement Study Report* (2017) by evaluating the Pine Creek Reservoir anchor project. The results of the feasibility study will be used to determine if moving forward with the Pine Creek Reservoir anchor project is appropriate. Extensive field and subsurface exploration is needed to refine our understanding of the active fault, subsurface conditions, and design requirements/construction costs for a dam. The seismic fault study, the geotechnical borehole drilling work with its televiewer logging and packer testing, combined with the soil lab testing, field engineering, water availability from both the Walla Walla River and Pine Creek, complete Oregon's storage-specific study requirements for Pine Creek, and engineering evaluation and costing is an essential next step to determining the feasibility, costs and benefits of proceeding with the Pine Creek Reservoir project to improve Walla Walla River stream flows. This feasibility study will provide needed information about the faultline in the vicinity of the dam site, geolocal conditions including stability and porosity that will inform dam layout (height, width, extent of grout curtain work under the dam) and dam costing, and the storage effectiveness. The hydrologic, water availability, bypass and peak flow analysis of both the Walla Walla River and Pine Creek will determine water availability for storage. The Pine Creek Reservoir has been identified as one of the two most likely methods (or anchor projects), along with a possible Columbia River Water Exchange, to achieve the Flow Study's stream flow targets. Having more informed cost estimates for the construction, operation and maintenance, and a water storage performance evaluation, of the Pine creek reservoir will enable a better cost comparison to the Columbia River Water Exchange project, which is the only other large alternative water source project being considered to replace irrigation water demands.

Flow restoration targets at 8 management points along a 40 mile reach of the Walla Walla River have been agreed to by the Walla Walla Basin Integrated Flow Enhancement Study Steering Committee. Either the Pine Creek Reservoir, using water stored from both Pine Creek and the Walla Walla River during winter and spring months, or a Columbia River Pump Exchange would provide water for the five participating irrigation districts. This would allow a corresponding amount of their existing Walla Walla River water rights that would have been available to them each irrigation season at their typical points of diversion to be left instream to improve stream flows for passage and habitat needs of ESA-listed steelhead and bull trout, and for spring Chinook salmon reintroduced to the Walla Walla Basn by the CTUIR. Currently modeled flows from 35,000 acre feet of re-timed water would double or even triple existing stream flows in the Walla Walla River from Milton-Freewater, Oregon downstream to the Touchet River Confluence in Washington. Instream flow targets range from 150 cfs in the spring to 65 cfs in the summer. Currently summer flows can be as low as 10-25 cfs depending on which management point is looked at.

The flow targets agreed to by the Walla Walla Basin Integrated Flow Enhancement Study (WWBIFES) Steering Committee are the following:

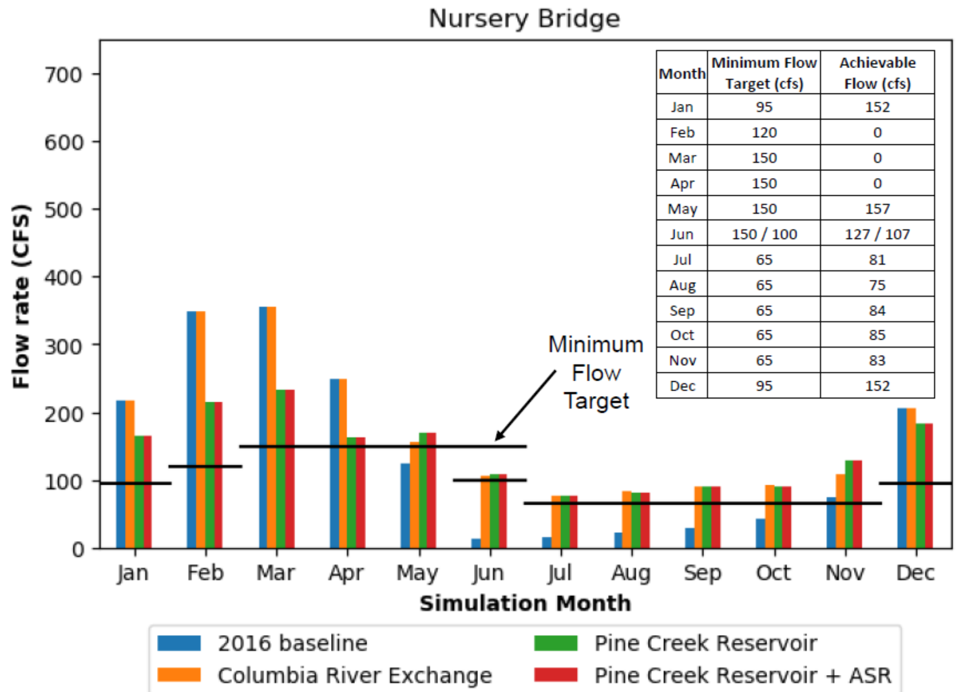
Time Period	Flow Study Flow Targets
April 1—June 15	**150 cfs**
June 16—June 30	**100 cfs**
July 1—November 30	**65 cfs**

Flow Study Management Points are shown below as yellow circles where there are flow gauges along the river to document stream flow improvements in Oregon and Washington.



<u>The image below shows the modeled results of the proposed Pine Creek Reservoir in achieving flow improvements at the Flow Study Management Point immediately downstream of Milton-freewater, Oregon as compared to baseline conditions, and the Columbia River Pumped Water Exchange Project.</u>

- Nursery Bridge flow
  - Minimum flow target not met in baseline model in May through October
  - Minimum flow target and achievable flow not met in first half of June (150 cfs and 117 cfs)



9. Describe the identified water need (local, regional, or statewide). Please provide data or a narrative substantiating the need.

The Walla Walla River does not provide adequate water amounts to serve the needs of both fish and farms. There is currently no water storage facility in the Walla Walla valley. Up until the last decade, portions of the Walla Walla River were completely dewatered in the summer due to irrigation withdrawals and riverbed seepage. A flow bypass agreement program that has been based on an aggressive irrigation efficiency progran implemented over the last nineteen years has improved flows for fish, but additional flows are needed to improve fish passage and habitat goals. Over 25 cfs of irrigation water rights have been converted to instream flows with their original water right dates and the river no longer goes dry, fish populations have not rebounded. More instream flows are needed. The OWRD Water Availability Report shows 160,000 acre feet of natural flow in the Walla Walla River at Milton-Freewater, with 46,800 acre feet of that being available after meeting consumptive use and instream flow requirements. Pine Creek water would be added to this, with a combined 16,310 acre feet of natural stream flow, and net water available after consumptive uses of 13,590 acre feet.

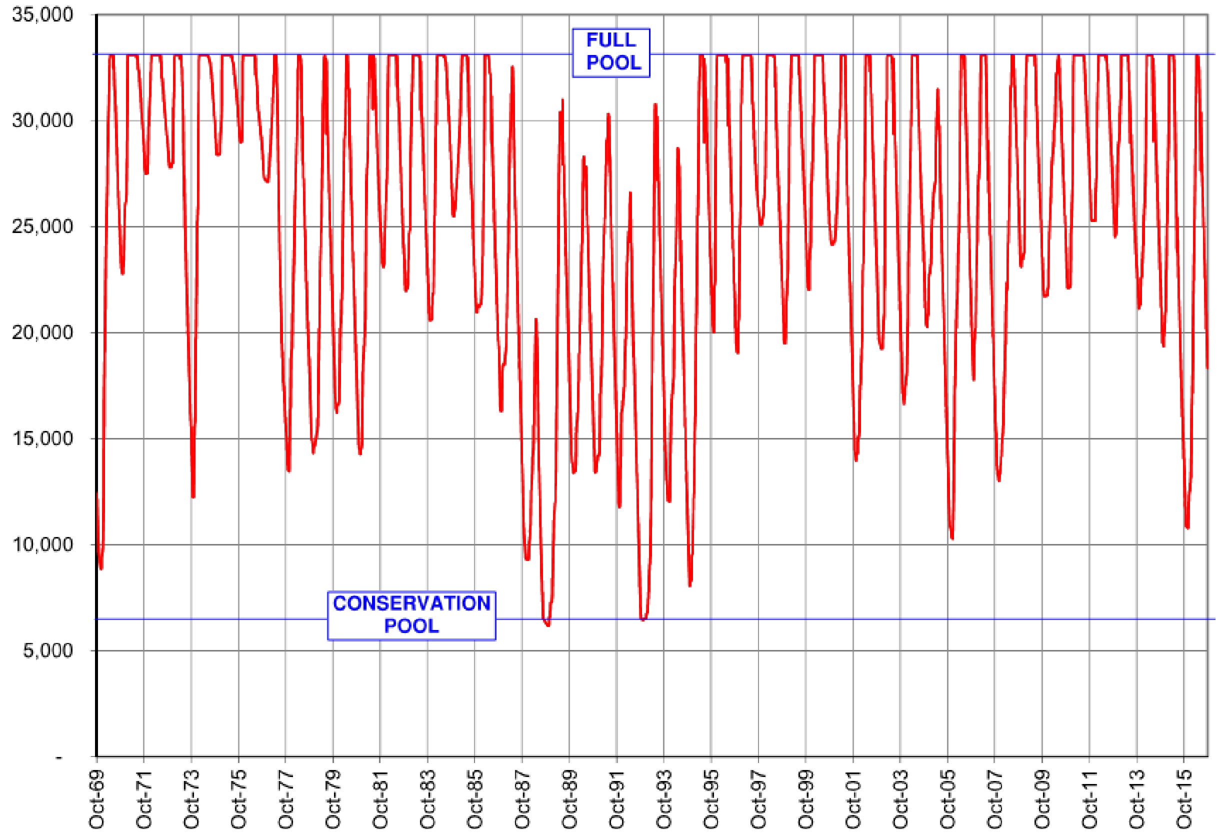
To attain the flow targets at the 8 management points along the river we need around 35,000 acre feet of water so the lower reservoir site, which can store up to 28,000 acre feet a year, would need to be coupled with other projects such as the expanded City of Walla Walla ASR project, and possibly the Gardena Farms/Lowden 10 cfs pump loop project, and other projects.

In addition to this reservoir project's primary goal of increasing streamflows for fish, the expected impacts of climate change on the hydrograph will only heighten the need for storage due to warmer spring conditions and earlier snow melt. (*Walla Walla Basin Integrated Water Flow Model: Alternative Climate Scenario Water Resources Report*, GeoSystems Analysis, 2017). Local growers can no longer turn to groundwater to meet future needs because of the Serious Water Management Problem Area (SWMPA) designation restricting additional basalt aquifer use, and no more alluvial aquifer irrigation permits are being issued.

10. Please provide evidence that water is available to meet the above described need. Evidence can include regulatory and physical information regarding water availability.

An earlier assessment of Walla Walla River water availability utilized the following Oregon storage project required methodology and had the following results. Walla Walla River historical flow measurements were used to develop a continuous daily record for 47 years from October 1, 1969, to September 30, 2016. The total is the sum of multiple gages, with some data gaps filled by correlations with other gages. Pine Creek historical flow measurements were used to develop a continuous daily record for 47 years from October 1, 1969, to September 30, 2016. Data gaps and extension of records were determined with correlations of other gages. Reservoir Filling Period The State of Oregon regulations limit the period of filling the reservoir from November 1 in the late fall through the winter to May 31 the following spring. The dates for filling typical do not restrict the ability to fill the reservoir as the dates align with when the water supply is available given the instream flow targets and irrigation demands. The water directly available from the Walla Walla River for meeting irrigation demands after satisfying the instream flow targets, would be diverted using the Little Walla Walla Diversion. From the intake, water is conveyed to the FROG for distribution in the Little Walla Walla River and on to a purpose built conveyance pipelinte to the reservoir. Direct flow will have the seepage loss of the Little Walla Walla River. The remaining irrigation demand is satisfied using the reservoir.
The assumed river intake capacity is 270 cfs. The existing river intake has a design capacity of 220 cfs that will require modifications to the downstream control to achieve the capacity. An additional 50 cfs of secondary capacity was assumed to be added to the existing river intake to capture higher river flows and provide redundant capacity for maintenance or break downs of the primary fish screens.
It is assumed that there is no water being diverted when the Walla Walla River flows increase rapidly for 18 hours to let the first flush of debris and sediment pass in the river and not compromise the river intake or the conveyance pipeline to the reservoir.
At flows above 2000 cfs it is assumed that only 20 cfs is being diverted for keeping the irrigation system watered up while reducing the risk to the system from debris in the river and movement of gravels on the river bed.
Reservoir performance is defined by quantifying the firm yield. The firm yield of a reservoir is typically defined as the maximum yield that could have been delivered without failure during the historical

drought of record. As such, it is representing the worst historical scenario. The historical drought of record is the years leading up to and following WY 1988. The reservoir system can provide 18,400 AF in those conditions which is an average of approximately 43 cfs from May 1 thru November 30 (213 days). Over the 47 years of the simulation, there were 5 years with shortages for the reservoir. Many reservoirs do not fill every year and still achieve the objectives of meeting demands and not having shortages. Reservoir filling though is an indicator of whether the reservoir is sized appropriately for the water supply while meeting demands. The reservoir would fill 80 percent of all 47 historic years.



Fill and Empty Cycle of the Active Storage for the Reservoir During the 47-Year Simulation. Note: The flow study is now considering a 28,000 acre foot reservoir, rather than the 34,000 acre foot above.

This water availability analysis of source water using the Oregon methodology from the Walla Walla River in winter and spring, has been completed by our consulting team, in coordination with input from decades of stream flow gauge data and in consultation with OWRD staff and OWRD water availability reports. The consulting team did not have the time and budget to complete the same analysis for capturing Pine Creek flow while allowing bypass flow and peak flows to remain in Pine Creek. We now know that we need to review and revise this Walla Walla River water availability assessment to factor in the Division 33 rules which limit diversions after April 15 of each year in tributaries to the Columbia River, rather than the reservoir fill period continuing to May 31. The review and update of the Walla Walla River water availability analysis will also include factoring in the flow bypassa amounts each month for the Washington instream flow rule, and coordinate with both OWRD and WDOE to evaluate whether an environmental enhancement project justification based on the signicanyt flow improvements to the Walla Walla River can be utilized to create some flexibility in both Oregon's and Washington's rules. We are also intending to investigate the best storage water right method, whether it is a storage water right or exchange with irrigation districts and existing landowner year round water rights, or a combination of the two. The potential project would provide an alternative water source for irrigation districts when Pine Creek Reservoir water is available. There is also a task to complete the Oregon storage-specific requirements methodology of analysis of Pine Creek water availability which will include an analysis of ecological flows, and documentation of the comparative analyses of alternative water supply projects that have been completed, analysis of environmental impacts from the proposed storage project, documentation of the project's ability to meet instream flow needs.

11. Describe the level of community support and commitment associated with the study. This may include any collaborative water planning efforts undertaken to identify the project or study.

This Pine Creek Reservoir project has been identified as a priority project to be investigated by the ongoing Walla Walla Basin Integrated Flow Enhancement Study. In 2014, building on previous efforts, the the Walla Walla Basin Watershed Council (WWBWC), and its Washington counterpart, the Walla Walla Watershed Management Partnership (WWWMP) worked with CTUIR and the Washington Department of Ecology to convene a steering committee to develop strategies to meet instream flow objectives while preserving existing diversionary requirements. The objective of this Flow Study is to determine the best package of options for achieving Walla Walla River instream flow targets for native fish species while maintaining the long-term viability and water availability for irrigated agriculture, residential, and urban use. The Flow Study intends to identify strategies to meet instream flow demands while providing opportunities to protect and enhance municipal and agricultural needs. The Steering Committee consists of tribal, state, and local governments, as well as irrigation, municipal, and environmental interests to guide strategy development. The Steering Committee developed and screened a broad range of projects (e.g., conservation, storage, source exchanges, aquifer recharge, water markets), then grouped them into alternatives to evaluate their ability to meet Flow Study objectives. The Steering Committee is now leading the next steps consisting of feasibility studies on the Alternatives, environmental review, expanded outreach, addressing Oregon-Washington joint decision-making strategies, and other efforts designed to move toward selection of a Preferred Alternative in the 2019-2021 biennium.

The Flow Study Steering Committee approved the Reservoir Study as part of the priority tasks to be completed this biennium and are interested in this study occurring, including adding the Oregon funding to create a more robust study of the Pine Creek Reservoir Projects' feasibility.

Flow Study Steering Committee Membership

Voting Members: Attend meetings, review materials, provide feedback, and vote.	
Gardena Farms Irrigation District (GFID)	Washington Water Trust
Walla Walla River Irrigation District (WWRID)	Washington Department of Fish & Wildlife
Hudson Bay District Improvement Company (HBDIC)	Oregon Department of Fish & Wildlife
Bergevin – Williams and Old Lowden Irrigation	City of Walla Walla
Fruitvale Water Users Association	City of Milton-Freewater
Confederated Tribes of the Umatilla Indian Reservation (CTUIR)	Kooskooskie Commons
Ex-Officio Members: Same as voting members but without voting authority	

Walla Walla Watershed Management Partnership (WWWMP)	Trout Unlimited
Walla Walla County Conservation District	Columbia County Conservation District
Walla Walla Basin Watershed Council (WWBWC)	Umatilla County Soil and Water Conservation District
Oregon Water Resources Department (OWRD)	U.S. Fish and Wildlife Service (USFWS)
Washington Department of Ecology	National Oceanic and Atmospheric Administration
	Oregon Department of Environmental Quality
Advisory Members: Kept updated and can provide input to the level desired but meeting attendance optional.	
Umatilla County Commissioners	Washington Department of Agriculture
Walla Walla County Commissioners	Oregon Department of Agriculture
Columbia County Commissioners	U.S. Corps of Engineers
U.S. Congressional Staff	Bureau of Reclamation
State elected officials/ Staff	U.S. Forest Service
National Resources Conservation Service	Snake River Salmon Recovery Board
The Freshwater Trust	Tri-State Steelheaders

12. Describe how implementation of the project could benefit and/or impact the community.

The purpose of the off-channel dam and conveyance system is to capture and store winter and spring runoff from the Walla Walla River and Pine Creek, and make the water available for irrigation needs later in the spring, summer, and fall. By using the stored water to meet the irrigation demands, significantly more water can be left in the Walla Walla River as instream flows to enhance aquatic life, fish passage, and other ecological values. The Project would increase the total available water supply to the region and change the timing of water deliveries to benefit both agriculture and fish migration in the Walla Walla River.This project would reduce ESA pressures on local irrigation districts to leave more water (as much as 28,000 acre feet to be released over a multi-month period to maintain in stream flow targets for for ESA protected species and for culturally significant salmon. The reservoir would create a more dependable water source for irrigators as there is the potential for carryover stored water from good water years to a following poor water year . The reservoir would also expand wildlife and recreational opportunities in the Walla Walla Basin where we currently do not have any large water storage reservoirs.

13. List letters of support (name and/or affiliation of sender). Attach copies of the letters to your application.

    Walla Walla County Conservation District
    Walla Walla Water Management Partnership

Study Key Tasks

14. Identify the study key tasks necessary to conduct the feasibility study using the following format and including as many tasks as necessary to complete the study. In the event that your study receives grant funding, the key tasks identified will be incorporated into your grant agreement as the "Statement of Work." Please note: Project management and administration are common functions within a specified key task and not separate key tasks themselves.

Task number. Key Task Title

- Task schedule: The approximate dates during which the key task will be completed.
- Description of key task activities: Include specific details of the task such as task purpose, planned approach, appropriate technical information, proposed methods, and rationale for the approach.
- Qualified personnel that will complete task: Include a description of the professional experience, professional qualifications and licensure of personnel necessary for task work.

Task 1. Geotechnical Feasibility Study of the Pine Creek Reservoir Site

- Task schedule: February 2020 - June 2021

Description of key task activities: Extensive field and subsurface exploration to refine understanding of active fault, subsurface conditions, and design requirements, and construction costs for dam. This work will include:
Five to six borings will occur along the centerline of the dam. Parameters of interest would include the top of bedrock, strength of the rock, the degree and orientation of jointing and fracturing, the presence of other rock types besides basalt, and the permeability of the rock mass. Most boreholes will be vertical but some may be inclined.

Proposed in situ testing will include the following:
• Water pressure (packer) tests to estimate the permeability of the rock mass.
• Optical and acoustical tele-viewer logging in the holes to record continuous color images of the in situ rock. The purpose of this logging will be to determine the nature of the rock in zones of potential rock core loss and to evaluate the nature and orientation of joints, shears, bedding and other discontinuities in the rock.

Follow up lab testing and engineering evaluation and a technical report of findings.

The Pine Creek Reservoir alternative was identified as one of two anchor projects in the *Walla Walla Basin Integrated Flow Enhancement Study (2017)*. The reservoir alternative feasibility and data analysis is to include a site-specific fault study, a suitable borrow material source evaluation, and a conceptual design for an earth-core rockfill dam. The previously completed desktop geologic study indicated that a splay from the Wallula Fault System likely extends through the proposed dam foundation. The site-specific fault study will determine the location, the sense of slip direction, and the potential rupture height and length of the Pine Creek fault trace. The borrow material source evaluation will determine if there is suitable borrow material near the reservoir site and if it will be economically feasible to construct the dam core. If the site-specific fault study and the borrow material source evaluation do not identify a fatal flaw with the Pine Creek Reservoir alternative, then a new conceptual design for an earth-core rockfill dam will be completed for the site. The conceptual design of the dam will include the approximate material volume needed, and this volume will be compared to the approximate volume of suitable borrow source material identified. The conceptual design will also include cost estimates for construction and annual operations and maintenance for the new dam.

Task 1. Expected Outcome:
This feasibility and data analysis will build upon information in the *Walla Walla Basin Integrated Flow Enhancement Study (2017)* by evaluating the Pine Creek Reservoir anchor project. This feasibility and data analysis includes a fault study, borrow material source evaluation, and a conceptual design for an earth-core rockfill dam. The results of the reservoir alternative feasibility and data analysis will be used to determine if moving forward with the Pine Creek Reservoir anchor project is appropriate.

Qualified personnel that will complete task: The Jacobs Engineering, Inc/CH2M Hill Engineers, Inc./GeoSystems Analysis, Inc. /ASPECT Consulting, LLC/Water Resource Solutions consulting team was hired through a competitive RFP process and includes licensed engineers specializing in large scale dam and pump and pipeline designs and construction, licensed hydrologists, licensed geologists, licensed hydrogeologists, biologists, and water right specialists. Several members of this team have been working on water issues in the Walla Walla Basin since the early 2000s and have a thorough understanding of the Basin, and have experience with similar projects, and with some aspects of this study will be expanding upon, and refining, work that they have initiated under previous contracts. The personnels' qualifications include assessment and design, and construction oversight of dams and reservoirs, including recent work in Washington state, Alabama, and Africa. CH2M also had a lead role in developing the Yakima Basin Water Plan which included the feasibility analyses of both new reservoir construction and expansion of existing dam heights and existing reservoir capacities.

Task 2. Complete Oregon's storage-specific study requirements for diverting a portion of the Walla Walla River for Pine Creek Reservoir filling, including verifications of the hydrology data, water availability data, analysis of ecological flows, and revise the time period to be utilized for filling, and factor in the instream flow requirements in both Oregon and Washington.

- Task schedule: June 2020 - June 2021

- Description of key task activities: Complete and verify the Oregon storage-specific study requirements. Verify the time period to be utilized for filling the Pine Creek Reservoir, and factor in the instream flow requirements in both Oregon and Washington.

This will include the following tasks:

Analyses of Ecological Flows
• Describe how the study assesses the impact of the storage project on bypass, optimum peak, and flushing flows (refer to the technical portion of this document for acceptable analyses)
• Describe how the study assesses project impacts on other ecological flows specific to the site or project

Comparative Analyses of Alternatives Means of Supplying Water

• Provide a list of alternative means of supplying water for comparison
• Describe the study methods to compare the alternative means of supplying water with the proposed storage project

Analyses of Environmental Harm or Impact
• Describe the analyses of environmental harm or impact incorporated to evaluate impacts on:

- State or federally listed sensitive, threatened or endangered fish species, native fish species of cultural importance to Indian tribes, and riparian habitat important for wildlife
- Groundwater levels
- Quality of surface water or groundwater
- Ecosystem resiliency to climate change impacts
- Limiting ecological factors in the project watershed

Evaluation of Need and Ability to Augment Instream Flows
• Describe the study methods to determine any need to augment instream flows to conserve, maintain and enhance aquatic life, including fish, and any other ecological values
• Describe the analyses for determining the potential for and feasibility of instream flow augmentation

Verify the time period to be utilized for filling the Pine Creek Reservoir related to Oregon's Division 33 Rules for water use in tributaries to the Columbia River.

Factor in the instream flow requirements in both Oregon and Washington, and provide a justification based on the proposed project's substantial summertime flow improvements if a variance is necessary.

Task 2. Expected Outcome:
This feasibility and data analysis will build upon information in the *Walla Walla Basin Integrated Flow Enhancement Study (2017)* by evaluating the Pine Creek Reservoir anchor project. This feasibility and data analysis includes an analysis of Walla Walla River water availability and ecological bypass flow analyses, and the reservoirs' performance in meeting the stream flow targets. The results of the reservoir alternative feasibility and data analysis will be used to determine if moving forward with the Pine Creek Reservoir anchor project is appropriate.

Qualified personnel that will complete task: The Jacobs Engineering, Inc/CH2M Hill Engineers, Inc./GeoSystems Analysis, Inc. /ASPECT Consulting, LLC/Water Resource Solutions consulting team was hired through a competitive RFP process and includes licensed engineers specializing in large scale dam and pump and pipeline designs and construction, licensed hydrologists, licensed geologists, licensed hydrogeologists, biologists, and water right specialists. Several members of this team have been working on water issues in the Walla Walla Basin since the early 2000s and have a thorough understanding of the Basin, and have experience with similar projects, and with some aspects of this study will be expanding upon, and refining, work that they have initiated under previous contracts. The personnels' qualifications include assessment and design, and construction oversight of dams and reservoirs, including recent work in Washington state, Alabama, and Africa. CH2M also had a lead role in developing the Yakima Basin Water Plan which included the feasibility analyses of both new reservoir construction and expansion of existing dam heights and existing reservoir capacities.

Task 3. Complete Oregon's storage-specific study requirements for Pine Creek and the proposed Pine Creek Reservoir, including verifications of the hydrology data, water availability data, analysis of ecological flows, revise the time period to be utilized for filling, and factor in the instream flow requirements in both Oregon and Washington.

- Task schedule: June 2019 - June 2021

Description of key task activities: Perform Pine Creek Storage-specific study requirements. These will include the following tasks:

Analyses of Ecological Flows
• Describe how the study assesses the impact of the storage project on bypass, optimum peak, and flushing flows (refer to the technical portion of this document for acceptable analyses)
• Describe how the study assesses project impacts on other ecological flows specific to the site or project

Comparative Analyses of Alternatives Means of Supplying Water
• Provide a list of alternative means of supplying water for comparison
• Describe the study methods to compare the alternative means of supplying water with the proposed storage project

Analyses of Environmental Harm or Impact
• Describe the analyses of environmental harm or impact incorporated to evaluate impacts on:

- State or federally listed sensitive, threatened or endangered fish species, native fish species of cultural importance to Indian tribes, and riparian habitat important for wildlife
- Groundwater levels
- Quality of surface water or groundwater
- Ecosystem resiliency to climate change impacts
- Limiting ecological factors in the project watershed

Evaluation of Need and Ability to Augment Instream Flows
• Describe the study methods to determine any need to augment instream flows to conserve, maintain and enhance aquatic life, including fish, and any other ecological values
• Describe the analyses for determining the potential for and feasibility of instream flow augmentation

Task 3. Expected Outcome:
This feasibility and data analysis will build upon information in the *Walla Walla Basin Integrated Flow Enhancement Study (2017)* by evaluating the Pine Creek Reservoir anchor project. This feasibility and data analysis includes an analysis of Pine Creek water availability and ecological bypass flow analyses, and the reservoirs' performance in meeting the stream flow targets. The results of the reservoir alternative feasibility and data analysis will be used to determine if moving forward with the Pine Creek Reservoir anchor project is appropriate.

- Qualified personnel that will complete task: The Jacobs Engineering, Inc/CH2M Hill Engineers, Inc./GeoSystems Analysis, Inc. /ASPECT Consulting, LLC/Water Resource Solutions consulting team was hired through a competitive RFP process and includes licensed engineers specializing in large scale dam and pump and pipeline designs and construction, licensed hydrologists, licensed geologists, licensed hydrogeologists, biologists, and water right specialists. Several members of this team have been working on water issues in the Walla Walla Basin since the early 2000s and have a thorough understanding of the Basin, and have experience with similar projects, and with some aspects of this study will be expanding upon, and refining, work that they have initiated under previous contracts. The personnels’ qualifications include assessment and design, and construction oversight of dams and reservoirs, including recent work in Washington state, Alabama, and Africa. CH2M also had a lead role in developing the Yakima Basin Water Plan which included the feasibility analyses of both new reservoir construction and expansion of existing dam heights and existing reservoir capacities.

Copy and paste additional tasks as needed.

15. Study Task Scheduling – Estimated duration of feasibility study: February 2020 to June 2021

Place an “X” in the appropriate column to indicate when each task of the project would take place. Study tasks should match those listed as part of your response to the previous question.

Feasibility Study Key Tasks (Add additional rows as needed)	**Grant year**				**Grant year**				**Grant year**			
	2020				2021							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Geotechnical study of Pine Creek Reservoir site	☒	☒	☒	☒	☒	☒	☐	☐	☐	☐	☐	☐
Pine Ck Reservoir Fill, Walla Walla River flow analysis	☐	☒	☒	☒	☒	☒	☐	☐	☐	☐	☐	☐
Pine Ck Reservoir Fill, Pine Ck flows	☐	☒	☒	☒	☒	☒	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Permits and Regulatory Approvals

16. Identify any water rights required needed to complete the proposed Feasibility Study below. Check all of the following that apply and provide the information requested:
    a. ☒ No water rights are required to complete the proposed study.
    b. ☐ The proposed study requires a new water right or other water right transactions. If checked, list the transaction(s) required (e.g., new right, transfer, etc.):
    c. ☐ The applicant has legal access to a water right that will be used to conduct the study. The proposed study requires a water right, and the applicant holds or has been given permission to utilize the water right(s) for the proposed study. If checked, list all water rights required for the study in the table below, adding rows as needed. See the Application Instructions for further guidance, including how to find water right information.

Water Right Number (Include prefixes, if applicable, e.g., CW 12345)	Is this an application, permit, certificate, limited license, special or final order, transfer, decree, lease, or claim?	Tax Lot IDs within the Place of Use where water will be used to complete the study

17. Identify any water rights needed to implement the proposed Project below. Check all of the following that apply and provide the information requested:
    a. ☒ The applicant does not know what water rights or water right transactions are required for the project. That will be determined through this study or other effort at a future date.
    b. ☐ The proposed project requires a new water right or other water right transactions. If checked, list transaction(s) required (e.g., new right, transfer, etc.):
    c. ☐ The applicants holds the water right(s) required for the project. If checked, include list of rights in the table below, adding rows as needed. See the Application Instructions for further instruction, including how to find water right information.

Water Right Number (Include prefixes, if applicable, e.g., G 00010)	Is this an application, permit, certificate, limited license, special or final order, transfer, decree, lease, or claim?	Water Right Amount			Tax Lot IDs within the Place of Use where water will be used to implement the proposed project
		Max Volume (ac-ft)	Max Rate (cfs)	Duty (ac-ft/ac)	

18. Provide a list of any other permits and regulatory approvals needed to conduct the Feasibility Study and indicate the status of each in the table below. If permits/approvals are required, please submit copies of secured permits/approvals **or** describe efforts to secure permits/approvals including status. If no permits or authorizations are required for the study, provide an explanation: no permits are needed

Study Permit/ Regulatory Approval	**Status and Efforts To Date**

19. Provide a list of the permits and regulatory approvals that you anticipate would be needed to implement the proposed project being studied. If permits/approvals are not required, please explain why and provide information regarding any agencies contacted to verify this determination:

Project Permit/Regulatory Approval *(add rows as needed)*

VI. Feasibility Study Budget

Instructions: Please answer the following questions about the study budget using the tables provided.

20. Please provide an estimated line item budget for the proposed feasibility study. Examples include: Direct project specific costs, such as in-house staff salary, contractual services, and administrative costs. See the Department's Budget Procedures and Allowable Costs for further guidance.

OVERALL STUDY BUDGET Line Items	**Number of Units*** *(e.g. # of Hours)*	**Unit Cost** *(e.g. hourly rate)*	**In-Kind Match**	**Cash Match Funds**	**OWRD Grant Funds**	**Total Cost**
Staff Salary/Benefits				3,500	8,476	11,976
Contractual/Consulting				186,350	87,500	273,850
Equipment (must be approved)						
Supplies						
Travel						
Other:						
Administrative Costs**				9,000	10,000	19,000
		Total		**198,850**	**105,976**	**304,826**

** The "Unit" should be per "hour" or "day" – not per "project" or "contract." Units x Unit Costs = Total Cost*
*** Administrative Costs may not exceed 10% of the total funding requested from the Department*

21. Identify the budget for each key task below. Key tasks identified below should be the same as the key tasks identified in Questions 14 and 15.

Feasibility Study Key Tasks **(Add additional rows as needed)**	**In-Kind Match**	**Cash Match Funds**	**OWRD Grant Funds**	**Total Cost**
Task 1 Pine Ck Reservoir geotechnical study		*175,350*	*79,476*	*254,826*
Task 2 Pine Ck Reservoir Fill, Walla Walla River flows		*6,000*	*7,000*	*13,000*
Task 3 Pine Creek water availability/flow analysis		*8,500*	*9,500*	*18,000*
admin		*9,000*	*10,000*	*19,000*
Total		**198,850**	**105,976**	**304,826**

VII. Match Funding

Instructions: Please answer the following question regarding matching funds.

22. Please fill out the table below and attach the appropriate documentation for both the secured and pending match (add rows as needed). Keep in mind that applicants must demonstrate a minimum **dollar-for-dollar match**. Please note that a failure to meet this requirement or to attach documentation will result in an incomplete application that will not be considered for funding.

    For secured funding, you must *attach a letter of support or award* from the match funding source that specifically mentions the dollar amount identified for this study and as shown in the "Amount/Dollar Value" column in the table below.

    For pending resources, *other written documentation showing a request* for the matching funds must accompany the application or documentation must identify the date on which a future funding application will be submitted, identify the funding program, and provide evidence that the project is eligible for the funding program identified.

Match Funding Source (if in-kind, briefly describe the nature of the contribution)	**Type** **(✓ One)**	**Status** **(✓ One)**	**Amount/ Dollar Value**	**Date Match Funds Available** *(Month/Year)*
US Bureau of Reclamation	☒cash ☐in-kind	☐secured ☒pending	100,000	October 2020
Washington Dept. of Ecology	☒cash ☐in-kind	☒secured ☐pending	98,850	October 2019
	☐cash ☐in-kind	☐secured ☐pending		
	☐cash ☐in-kind	☐secured ☐pending		
	☐cash ☐in-kind	☐secured ☐pending		

VIII. Storage-Specific Questions

Instructions: If you indicated that your study is for a storage project, answer question 23 in this section. If your study is for above-ground storage, also answer question 24. Please refer to the document on Storage-Specific Study Requirements for guidance and information on completing this section, available on the OWRD Funding Opportunities, Applications, Forms, and Guidance webpage. If your study is for a water conservation or reuse project, skip this section.

23. Answer the following "Yes/No" questions about the storage project to be evaluated in the proposed study.

    A. Will the project divert more than 500 acre-feet of surface water annually? Yes ☒ No ☐

    B. Will the project impound surface water on a perennial stream? Yes ☐ No X

    C. Will the project divert water from a stream that supports sensitive, threatened or endangered species? Yes ☒ No ☐

    If you answered "yes" to any of the questions above, you are required to address the following analyses in your feasibility study. By signing this application, you are committing to include these required elements in your feasibility study.

    If you answered "yes" to (A), (B), or (C) above, attach a description of how you intend to address the following required elements in your feasibility study (please refer to the document on Storage-Specific Study Requirements for guidance and a description of the minimum acceptable standards regarding these study requirements):

    i. Initial analyses of by-pass, optimum peak, flushing and other ecological flows of the affected stream and the impact of the storage project on those flows were completed in 2017 for the Walla Walla River using the Oregon Storage Specific study Requirements. This work was not completed for Pine Creek. The Walla Walla River analysis incorporated OWRD Water Availability information along with the hydrologic record of data from state gages and WWBWC gages for the North Fork Walla Walla River, South Fork Walla Walla River, Mainstem Walla Walla River and Couse Creek. That analysis utlized the recommended methods, with input from OWRD, CTUIR and ODFW. A summary of that work is below. Much more work needs to occur on Pine creek where the analysis only factored in OWRD Water Availability data and then left a minimum instream bypass flow of 5 cfs through spring, summer, and fall months.

An initial Storage-Specific Study Flows analysis was completed in 2017 by the CH2M Engineers, Inc. consulting team and then been supplemented with an additional analysis by CTUIR Fisheries staff utilizing existing data. These analyses will be refined as part of this project based on the comments from OWRD and ODFW and any additional guidance, and local data, that is now available. The Water Supply Strategy completed by CH2M in 2017 followed the Oregon state guidance methodology available in 2017, as the project proposes to divert more than 15 percent of the flow of a river, an evaluation of specific resources occurred to justify the increased rate, and show that aquatic resources, including the physical functions of the channel, would be protected to a level acceptable by the state. The parameters assessed included the following:

Hydrology:
- Natural and altered hydrographs
- Recurrence intervals
- Exceedance probabilities

Hydraulics:
- Modeled depths, velocities
- Wetted area
- Modeled water surface elevations

Physical Processes:
- Channel flushing, maintenance, forming flows
- Floodplain/habitat connectivity flows
- Sediment transport flows

Biology:
- Migration triggers
- Spawning, incubation
- Juvenile rearing
- Adult fish passage

Flow and hydraulic data was paired with flow and habitat relationship information available from several studies completed in the Walla Walla River below the diversion over the past 17 years (such as instream flow studies and flood reoccurrence calculations). This effort provides river-specific correlations between Project flows and aquatic resources, rather than relying solely on theoretical comparisons and predictions. The hydrologists and engineers were able to incorporate a relatively large amount of the necessary modeling inputs, constraints, operational rules, etc., we have a high level of confidence that this analysis can present the direction and relative magnitude of the potential effects (both beneficial and detrimental) that the proposed Project would have on aquatic resources and give the Council several more pieces of useful information in helping to determine whether to move forward the proposed Project.

In general, because the proposed Project diverts water in the late-fall through spring months when river flow rates are highest and less important to the fish of biggest management concern (salmonids), the project benefits are expected to substantially outweigh any presumed negative impacts. In addition, because the Project would replace the perceived need by some individuals to irrigate outside of the irrigation season (or extra diversion during the irrigation season), the flows will be more predictable and more controllable at the diversion point. The lack of storage, and therefore predictability, often leads to less than optimal irrigation practices exacerbating any ongoing detrimental instream flow conditions.

The hydrology component comprises the Walla Walla River's historical flows upstream of the point of diversion (POD). Historical flows are used to perform the operational modeling for the reservoir, to develop the altered hydrographs downstream of the POD. The altered hydrographs demonstrate the performance of the Project to meet instream flow objectives while at the same time meeting the flow demands.

Fisheries Impacts on fish habitat in the Walla Walla River looked at limiting factors on the distribution and abundance of steelhead, bull trout, and Chinook Salmon. This included sediment loading, stream temperatures,and pool habitat, changes in wetted width as it relates to spawning and rearing habitat, and summer rearing flows.

The geomorphology section evaluates the flows required for channel maintenance in the Walla Walla River in the reach near the Point Of Diversion at Cemetery Bridge and estimates impacts to bed material movement, between the POD and the downstream railroad bridge, resulting from the Project. Extensive characterization of the channel bed substrate, bedload transport, channel geometry, and hydraulic conditions is required to establish the magnitude and duration of flows which form and maintain the channel, as well as provide floodplain connectivity.

ii. Comparative analyses of alternative means of supplying water, including but not limited to the costs and benefits of water conservation and efficiency alternatives and the extent to which long-term water supply needs may be met using those alternatives.

A comparative evaluation was developed and utilized to assess multiple stream flow enhancement actions that have been implemented or are currently in a planning or design phase. This will be refined as part of this project. The Pine Creek Reservoir project has been compared to the Columbia River pumped water exchange project exchange project. The comparisons have looked at costs to build and ongoing operations and maintenance costs, and performance comparisons related to ability to achieve the stream flow improvement management targets. The comparative reviews have also included smaller water projects. These showed that water conservation alone would not get us to meeting the goals. The valley has completed a significant amount of water conservation over the last 19 years resulting in 25 cfs instream with original irrigation dates in Oregon, and additional conservation work has occurred on the Washington side of the basin. Other projects such as a maximization of the City of Walla Walla'a Aquifer Storage and Recovery program and a Gardena Farms Irrigation District and Lowden Consolidated ditches Pump Loop Project are also being evaluated and may be combined with one of the large anchor projects.

See page 56 of the attached: *Walla Walla Basin Integrated Flow Enhancement Study Summary Report (2017)* for a detailed description of alternatives developed and and comparative evaluation tools developed to compare the costs/benefits, streamflow enhancement performance, secondary benefits, potential impacts, stage of development, and ongoing operation and maintenance considerations.

iii. Analyses of environmental harm or impacts from the proposed storage project.

This proposed storage project if implemented based on this feasibility study, will have the ultimate goal of significantly improving stream flows in the Walla Walla River for aquatic species, especially ESA listed steelhead and bull trout, and reintroduced spring chinook salmon. An initial analysis of impacts to the Walla Walla River has occurred, but will refined with additional flow, biological, and channel geomorphology data following the Oregon Storage Specific Study Requirements guidelines. However there will be impacts to Pine Creek, the intermittent stream where we are proposing a potential Pine Creek Reservoir site. Part of this feasibility study will be to complete an initial analysis of current conditions and any potential harm or impacts from this project on stream hydrology, any existing aquatic and terrestrial species, and channel geomorphology following the Oregon Storage Specific Study Requirements guidelines.

iv. Evaluation of the need for and feasibility of using stored water to augment instream flows to conserve, maintain and enhance aquatic life, fish life and any other ecological values.

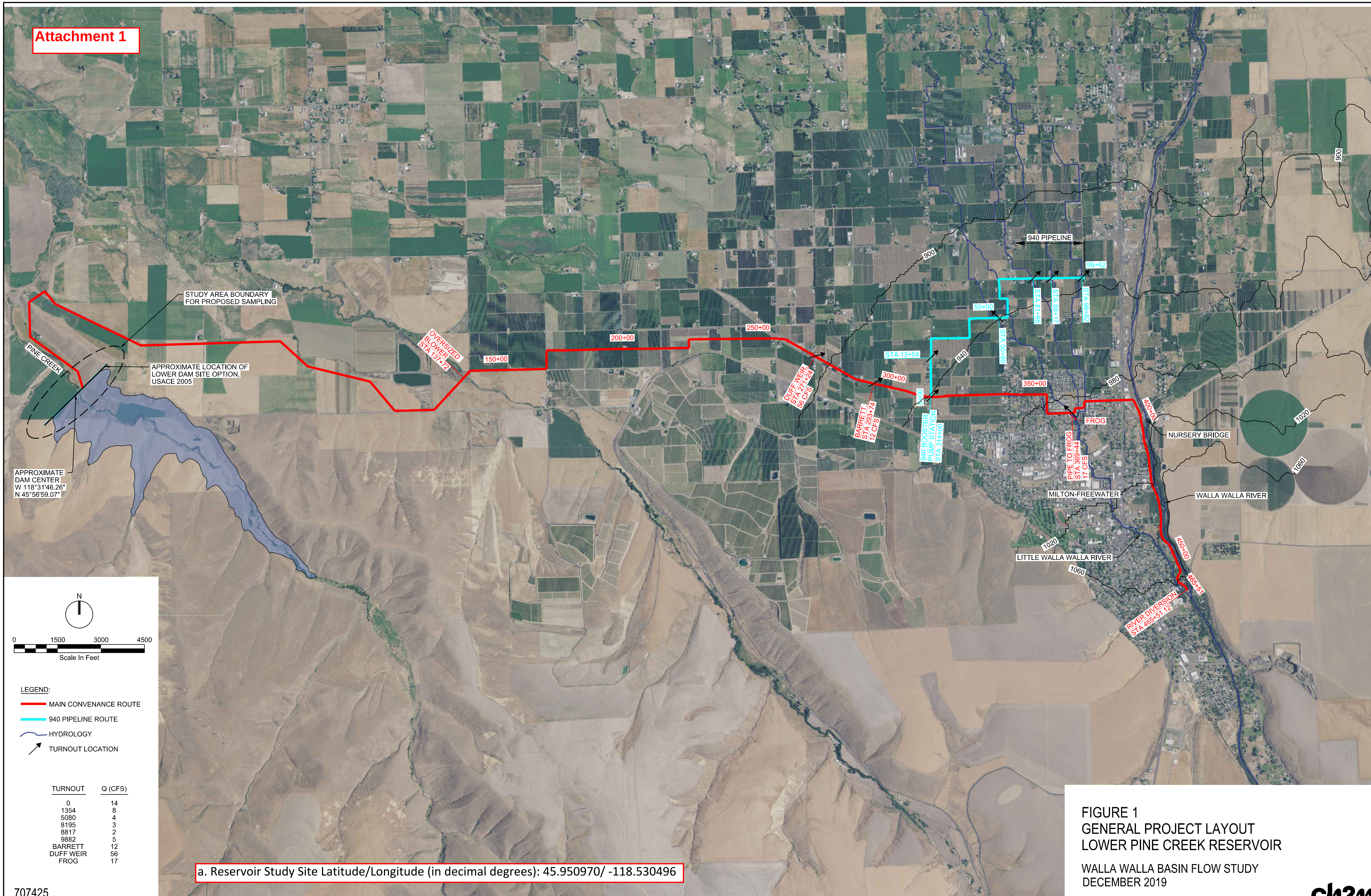
The primary objective of a Pine Creek Reservoir is to augment Walla Walla River flows to improve conditions for aquatic life and other ecological values. An initial evaluation has been completed on assessing the feasibility of these projects to augment instream flows, and this will be refined and expanded upon as part of this project. The need to augment flows will be determined by comparing OWRD's data on the surface water rights for diversions from the Walla Walla River in Oregon against instream flow targets from OWRD and the Walla Walla Basin Integrated Flow Enhancement Study which were based on minimum flows needed by fish. The results of the environmental flows analysis (of base, optimum peak, and flushing flows) to be conducted in Task 4 will be presented. The hydrological implications of increased diversions from the Walla Walla River during winter will be considered and compared against ecological benefits of increased flows during summer. To determine the potential for instream flow augmentation, the 47-year composite dataset developed in 2017 for the Pine Creek Reservoir study will be used to estimate inflow volumes to the area of interest. The Pine Creek Reservoir's ability to offset irrigation districts' water demand from the river in late spring, summer, and fall will increase streamflows by 50-100 cfs depending on the month of the year. These increased flow values will be included in the assessment. Increased instream flows resulting from the Pine Creek Reservoir project will be estimated using WWBWC's existing linked groundwater-surface water model, and the surface water river seepage model. Current instream flow conditions will be compared against several metrics, including minimum instream flow targets and the magnitude of impacts on surface water availability which resulted from recent irrigation efficiency improvements and approved conserved water applications that have improved instream flows, with the much more substantial Walla Walla River flow improvements from the potential pine creek reservoir improvements.

v. *For proposed storage projects for municipal use only* **–** For a proposed storage project that is for municipal use, analysis of local and regional water demand and the proposed storage project's relationship to existing and planned water supply projects.

Not applicable for this Feasibility Study.

24. **For Above-Ground Storage Only:** Describe whether or not the storage project would include provisions for using stored water to augment instream flows to conserve, maintain and enhance aquatic life, fish life or other ecological values. As per statute and rule, above-ground storage projects that include these provisions receive preference for funding over other storage projects.

This project is solely designed to improve stream flowfor aquatic life, fish life, and other ecological values in the Walla Walla River, while maintaining existing out of stream water uses. The pine creek reservoir if implemented wil l double and even triple stream flows in reaches of the river that currently are reduced down to 25 and even 5 cfs each summer. Those reaches are anticipated to be maintained at 50 - 65 cfs all summer, a substantial improvement that will remove physical and thermal fish passage barriers , and expand spawning and rearing habitat for several more miles of the Walla Walla River.



TURNOUT	Q (CFS)
0	14
1354	8
5080	4
8195	3
8817	2
9882	5
BARRETT	12
DUFF WEIR	56
FROG	17

a. Reservoir Study Site Latitude/Longitude (in decimal degrees): 45.950970/ -118.530496

FIGURE 1
GENERAL PROJECT LAYOUT
LOWER PINE CREEK RESERVOIR

WALLA WALLA BASIN FLOW STUDY
DECEMBER 2019

ch2m:

FILENAME: PC-FigA-20_692935.dgn
PC-Fig01_692935.dgn
PLOT DATE: 2019\11\13
PLOT TIME: 12:13:26 PM

OREGON WATER RESOURCES DEPARTMENT

Feasibility Study Grants

Landowner Agreement

Instructions to Applicants: Work with landowners to complete this form for all properties accessed for the study or on which the proposed study would occur. Submit this completed form as part of your grant application. For questions contact WRD_DL_feasibilitystudygrants@oregon.gov.

Project and Applicant Information

Project Name: Pine Creek Reservoir Feasibility Study

Funding Applicant: Walla Walla Basin Watershed Council

Co-Applicant (if applicable): ______

Funding Applicant Contact Information:
Name: Brian Wolcott
Phone Number: 541-938-2170 x106
Email Address: brian.wolcott@wwbwc.org

Co-Applicant Contact Information:
Name: ______
Phone Number: ______
Email Address: ______

Landowner Information – *NOTE: Please include ALL landowners listed on the deed .*

Landowner(s) Name: Adolf Klein

Landowner's Authorized Representative: same

Landowner(s) Contact Information (or Authorized Representative)
(required) Address: 50036 Schubert Road
Milton-Freewater, OR 97862

(optional) Phone Number: 541-938-6850
(optional) Email Address: ______

Property Information

List each property owned by the above-mentioned Landowner(s) on which the study would occur:

County	Tax Map Number	Tax Lot Number
Umatilla County	6N34000004400	6N34000004400

Landowner Acknowledgement

1. Insert All Landowner Name(s) is/are the legal owner(s) (the Landowner) of the above described property (the Property).
2. I am authorized to act on behalf of the Landowner.
3. I am aware of and agree to the above-mentioned proposed study and grant permission for the Applicant, and the Applicant's agents, to conduct the following activities on the Property. (List activities below)

a.	Drill 5-6 boreholes for geological investigation
b.	Dig a fault line exploratory trench that will be filled back in and seeded after examination by geologist
c.	TOPSOIL WILL GO BACK ON TOP TWO FEET.
d.	

4. I certify that the above-mentioned information is true and accurate, I am aware of and agree to the proposed work, and I am authorized to sign as the Landowner or Authorized Representative.

Signature of Landowner(s) or Authorized Representative: Adolf Klein

Date: Nov 6 2019 Print Name: Adolf Klein

AMENDMENT NO. 2
TO AGREEMENT NO. WROCR-2018-WaWWMP-00001
BETWEEN
THE STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
AND
Walla Walla Watershed Management Partner

PURPOSE: To amend the above-referenced agreement (AGREEMENT) between the state of Washington Department of Ecology (ECOLOGY) and Walla Walla Watershed Management Partner (RECIPIENT) for the Walla Walla Basin Instream Flow Enhancement Feasibility Study (PROJECT).

Reallocation of $4,300 from Task 3 to Task 6, and $56,000 from Task 4 to Task 3 and to 4 new tasks. Modify Task 4 description and deliverables. Increase deliverable 3.1 amount by $10,000. Extend appropriate deliverable deadlines to 12/31/2019.

IT IS MUTUALLY AGREED that the AGREEMENT is amended as follows:

CHANGES TO THE BUDGET

Funding Distribution EG190001

Funding Title: Walla Walla Basin Instream Flow Enhancement Feasib

Funding Type: Grant

Funding Effective Date: 07/01/2018 Funding Expiration Date: 12/31/2019

Funding Source:

Title: Columbia River Water Supply Development Account

Type: State

Funding Source %: 100%

Description: Grants for the purpose of the assessment, planning and development of project that acquire and/or implement senior water rights, water conservation, water resuse, stream gaging, groundwater monitoring, and developing natural and constructed infrastructure designed to provide access to new water supplies.

Approved Indirect Costs Rate: Approved State Indirect: 30%
Recipient Match %: 0%
InKind Interlocal Allowed: No
InKind Other Allowed: No
Is this Funding Distribution used to match a federal grant? No

Walla Walla Basin Instream Flow Enhancement Feasib	Task Total
Feasibility Analysis and Data Gaps	$ 281,600.00
Environmental Review	$ 24,000.00
Pine Creek Reservoir Alternative Feasibility and D	$ 98,850.00
Extra Out-of-Scope Meetings	$ 3,100.00
Bennington Lake/Storage Add-On Characterization	$ 10,000.00
Unmitigated Groundwater	$ 9,500.00
Diversion Location/Audit	$ 15,000.00
Monitoring work	$ 15,000.00
Strategic Implementation Planning	$ 30,000.00
Project Administration/Management	$ 22,500.00
Total:	**$ 509,550.00**

CHANGES TO SCOPE OF WORK

Task Number: 3 **Task Cost:** $281,600.00

Task Title: Feasibility Analysis and Data Gaps

Task Description:
A Feasibility Analysis of the potential of all project options including that of surface water storage sites in the Pine Creek sub-basin.

Task Goal Statement:

The Feasibility study will identify, in coordination with appropriate Technical Work Groups and the Steering Committee along the way, (with the Walla Walla Basin Watershed Council being the technical point of contact), any additional data gaps necessary to achieve the feasibility analysis refinement and standardization tasks. The Steering Committee will determine if and how those data gaps are addressed. Currently identified data gap tasks include utilization of Bennington Lake for storage and an assessment of exiting data and modeling work.

Task Expected Outcome:

A feasibility analysis building upon information in the Walla Walla Bi-state Flow Enhancement Study (2017), including construction costs, operation and maintenance costs and water volumes (storage volumes and diversionary volumes), of all project options including that of surface water storage sites in the Pine Creek sub-basin. Priority emphasis will be placed on a water availability analysis to determine what amount of water could be diverted from the mainstem Walla Walla during winter months for later use. This task will also include project alternative pairing analyses, pairing options, and performance evaluations based on Steering Committee and Technical Work Group input.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
3.1	Advance a large scale infrastructure (Anchor) Project Engineering and Design; $131,200; Updated project designs consistent with project objectives and comparable to other projects. A review will be performed of existing engineering and design work for a storage reservoir and Columbia River pump exchange project alternatives. Analysis will include project flow output quantities, timing and location as it relates to achieving the flow target goals	
3.2	Advance smaller scale add-on Project Engineering and Design; $50,000; Updated project designs consistent with project objectives and comparable to other projects. Analysis will include project flow output quantities, timing and location as it relates to achieving the flow target goals. These include, but are not limited to the following potential projects: 1. GFID Loop, 2. Lowden Ditch, 3. White Ditch, and 4.Telemetry/Automation	
3.3	Water Availability Assessment; $20,000; Updated assessment of winter surface water availability in the headwaters of the Walla Walla Basin (located in Oregon). Assessment will include water availability from the Walla Walla River, Pine Creek, Dry Creek, Couse Creek, and Mill Creek.	
3.4	Bennington Lake Re-operation Assessment; $10,000; Updated project description, operational considerations, and cost estimate.	

3.5	Data and Modeling Assessment; $10,500; As data gaps are identified in developing the feasibility analysis, additional data collection and/or modeling may need to be performed. Data gaps filled to the extent possible and modeling, as necessary, to inform project packaging.	
3.6	Project Packaging; $59,900; The Walla Walla Flow enhancement study steering committee identified 5 project packages (series of projects) to implement to achieve enhanced streamflows in the Walla Walla Basin	

CHANGES TO SCOPE OF WORK

Task Number: 4 **Task Cost:** $24,000.00

Task Title: Environmental Review

Task Description:
Environmental review is a critical factor in timing the transition from flow study alternative development to implementation. This environmental review process includes a strong SEPA foundation followed by future NEPA integration and compliance. This task will develop the foundation for SEPA compliance and SEPA/NEPA integration for the Flow Study.

Task Goal Statement:
Prepare a memorandum of agreement for State Environmental Policy Act co-leadership with Ecology. Prepare a SEPA checklist documenting the proposed action. Prepare a Determination of Significance documenting the need for an environmental impact statement. Develop a resource library of foundational documents to be used during SEPA outreach and scoping. Develop a draft scope of work and budget for further environmental review for financial planning purposes.

Task Expected Outcome:
Appropriate documents (MOA, checklist, Determination of Significance, and scope of work) in place to launch SEPA scoping once Ecology and the Partnership agree on an integration strategy with the Walla Walla Water 2050 watershed plan.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	**Description**	**Due Date**
4.1	WWWMP and Ecology memorandum of agreement	12/31/2019
4.2	SEPA Checklist and draft Determination of Significance	12/31/2019
4.3	Resource Library	12/31/2019
4.4	Draft planning budget for SEPA EIS	10/07/2019

CHANGES TO SCOPE OF WORK

Task Number: 6 **Task Cost:** $98,850.00

Task Title: Pine Creek Reservoir Alternative Feasibility and D

Task Description:
The Pine Creek Reservoir alternative was identified as one of two anchor projects in the Walla Walla Basin Integrated Flow Enhancement Study (2017). The reservoir alternative feasibility and data analysis is to include a site-specific fault study, a suitable borrow material source evaluation, and a conceptual design for an earth-core rockfill dam. The previously completed desktop geologic study indicated that a splay from the Wallula Fault System likely extends through the proposed dam foundation. The site-specific fault study will determine the location, the sense of slip direction, and the potential rupture height and length of the Pine Creek fault trace. The borrow material source evaluation will determine if there is suitable borrow material near the reservoir site and if it will be economically feasible to construct the dam core. If the site-specific fault study and the borrow material source evaluation do not identify a fatal flaw with the Pine Creek Reservoir alternative, then a new conceptual design for an earth-core rockfill dam will be completed for the site. The conceptual design of the dam will include the approximate material volume needed, and this volume will be compared to the approximate volume of suitable borrow source material identified. The conceptual design will also include cost estimates for construction and annual operations and maintenance for the new dam.

Task Goal Statement:
The RECIPIENT will conduct, in coordination with appropriate Technical Work Groups and the Steering Committee, the Pine Creek Reservoir alternative feasibility and data analysis. This feasibility and data analysis will include the site-specific fault study, the borrow material source evaluation, and the conceptual design for an earth-core rockfill dam.

Task Expected Outcome:
This feasibility and data analysis will build upon information in the Walla Walla Basin Integrated Flow Enhancement Study (2017) by evaluating the Pine Creek Reservoir anchor project. This feasibility and data analysis includes a fault study, borrow material source evaluation, and a conceptual design for an earth-core rockfill dam. The results of the reservoir alternative feasibility and data analysis will be used to determine if moving forward with the Pine Creek Reservoir anchor project is appropriate.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
6.1	Fault study and borrow source identification, field work, and planning; $26,650; Observations and information pertinent to the fault study and borrow source identification will be submitted in the Fault Study Site Investigation Technical Memorandum and the Borrow Source Test Pit Exploration Plan	

6.2	Test pit exploration and excavation to verify suitability and available quantity of borrow source material; $12,900; Observations and information pertinent to the test pit exploration will be submitted in the Borrow Source Test Pit Logs. Samples of excavated soil will be collected and submitted for appropriate laboratory testing	
6.3	Soil sample laboratory testing for borrow material source evaluation; $19,000; Testing cost is based on three sites and incorporating a 10% contingency. Cost will be proportionately less for fewer sites. Written description of the laboratory findings will be submitted in the final report.	
6.4	Earth-core rockfill dam concept development; $25,000; Criteria for the new dam concept will be developed. Construction costs and operation and maintenance costs will be estimated. If the fault study or borrow material source evaluation identify a fatal flaw for the construction of the earth-core rockfill dam, then this concept development will not be performed. Concept drawings, construction costs, and annual operations and maintenance costs will be submitted.	
6.5	Fault study, borrow source material evaluation, and earth-core rockfill dam concept design final report; $15,300; Final report combining all observations and findings of work for this Pine Creek reservoir alternative feasibility and data analysis.	

CHANGES TO SCOPE OF WORK

Task Number: 7 **Task Cost:** $3,100.00

Task Title: Extra Out-of-Scope Meetings

Task Description:
Additional meetings to address the complexity of the remaining tasks and adequately address and integrate Steering Committee and Technical Work Group comments.

Task Goal Statement:
The additional meetings will coordinate the Steering Committee and the Technical Work Groups to address the complexity of issues facing the remaining and additional tasks.

Task Expected Outcome:
Meeting organization and execution to coordinate the Steering Committee and Technical Work Groups for completion of identified Flow Study tasks.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
7.1	PowerPoint or other presentation materials used for the Steering Committee meetings.	12/31/2019

CHANGES TO SCOPE OF WORK

Task Number: 8 **Task Cost:** $10,000.00

Task Title: Bennington Lake/Storage Add-On Characterization

Task Description:
Bennington Lake is an option to provide flow augmentation to the Walla Walla River to replace irrigation flow diversions in the lower river segments. This task is to identify potential instream benefits from existing and expanded storage at Bennington Lake. Bennington Lake is a potential add-on project for the USACE Mill Creek Flood Control Feasibility Study, and this task would allow the Steering Committee to provide input regarding Bennington Lake to the USACE.

Task Goal Statement:
The goal of this task is to identify the approximate volume of water that could potentially be diverted from Mill Creek to an expanded Bennington Lake to provide flow augmentation to the Walla Walla River to replace irrigation flow diversions in the lower river segments.

Task Expected Outcome:
The expected outcome is a technical memorandum that identifies the potential instream benefits from existing and expanded storage at Bennington Lake. This technical memo will be used to supplement the Flow Study Final Report and could be used by the WWWMP/WWBWC to provide input to the USACE on their Mill Creek study.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
8.1	Technical Memorandum	12/31/2019

CHANGES TO SCOPE OF WORK

Task Number: 9 **Task Cost:** $9,500.00

Task Title: Unmitigated Groundwater

Task Description:

It appears that only 5 mitigation certificates for exempt wells have been issued over the last 10 years, whereas nearly 500 wells have been installed in the basin. This task will evaluate the magnitude and impact of the lack of mitigation certificates in Oregon and Washington in both the historical context (previous 10 years) and the future potential based on projected growth in the basin.

Task Goal Statement:
The work under this task will characterize the potential of exempt wells to negatively impact restored stream flows by trying to quantify the magnitude of the issue and/or lack of mitigation certificates within the basin.

Task Expected Outcome:
The expected outcomes include retrieval of data within the basin from Ecology's well log database and OWRD spreadsheet output of the OR wells. There will be a screening out process to remove extraneous wells that will not affect the analysis (e.g. resource protection or decommissioned wells). The wells will be located using GIS, and the wells will be identified as either shallow/gravel or deep/basalt. The likely exempt well impact will be calculated for the last 10 years and for the potential future 10 year projected growth. The results will be included in the 2019 Flow Study Update report.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
9.1	GIS-based figure(s) for quantification of location/impacts.	12/31/2019
9.2	Incorporation of results into the 2019 Flow Study Update report.	12/31/2019

CHANGES TO SCOPE OF WORK

Task Number: 10 **Task Cost:** $15,000.00

Task Title: Diversion Location/Audit

Task Description:
This task will inform the Flow Study Steering Committee regarding the number, location, and status of diversions that will have to be considered in the implementation of any of the potential project package alternatives. Diversion data/information will be aggregated from multiple sources (Ecology, OWRD, WWWMP, WWBWC, and others). Data gaps in diversion information, metering data, reliability/curtailment information, and other sources will be developed. This information will be needed to inform the project pairing task and will inform the 30-year plan process.

Task Goal Statement:
This task will provide necessary information to the Flow Study Steering Committee regarding the number, location, and status of surface water diversions within the Walla Walla basin. This information will have to be available and considered in the implementation of any of the potential Flow Study project package alternatives.

Task Expected Outcome:
Data and information will be collected, aggregated, and incorporated into the 2019 Flow Study Update report. A diversion audit tool and aggregated comprehensive diversion information from multiple sources covering the Walla Walla River mainstem for Washington and Oregon and the Little Walla Walla River will be included. A working session will be conducted with key staff to review and assimilate data sources. The data gaps in diversion information, metering data, reliability/curtailment information and other sources will be developed and submitted.

Recipient Task Coordinator: Chris Hyland

Deliverables

Number	Description	Due Date
10.1	GIS model to organize and present the data/results.	12/31/2019
10.2	Meeting notes from the technical meeting with Ecology, WWWMP, WWBWC, and OWRD.	12/31/2019
10.3	Incorporation of results into the 2019 Flow Study Update report.	12/31/2019

Funding Distribution Summary

Recipient / Ecology Share

Funding Distribution Name	Recipient Match %	Recipient Share	Ecology Share	Total
Walla Walla Basin Instream Flow Enhancement Feasib	0 %	$ 0.00	$ 509,550.00	$ 509,550.00
Total		**$ 0.00**	**$ 509,550.00**	**$ 509,550.00**

AUTHORIZING SIGNATURES

All other terms and conditions of the original Agreement including any Amendments remain in full force and effect, except as expressly provided by this Amendment.

The signatories to this Amendment represent that they have the authority to execute this Amendment and bind their respective organizations to this Amendment.

This amendment will be effective 09/01/2019.

IN WITNESS WHEREOF: the parties hereto, having read this Amendment in its entirety, including all attachments, do agree in each and every particular and have thus set their hands hereunto.

Washington State
Department of Ecology

By: 11/5/19

G. Thomas Tebb, L.Hg., L.E.G. Date
Office of the Columbia River
Director

Walla Walla Watershed Management Partner

By: 10/18/19

Chris Hyland Date
Executive Director

Template Approved to Form by
Attorney General's Office

www.wwbwc.org
Walla Walla Basin Watershed Council
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

November 12th, 2019

Walla Walla Basin Watershed Council Resolution

Regarding Support of BOR Water Development Planning Proposal

The Walla Walla Basin Watershed Council resolves to support the November 13th 2019 application for $100,000 in Bureau of Reclamation Cooperative Watershed Management Program funds necessary to complete a Bi-State Water Development Plan. The Walla Walla Basin Watershed Council Board members voted to support this effort at their October 21st, 2019 Board meeting.

John Zerba

Chairman, Walla Walla Basin Watershed Council

DRAFT REPORT

Concept Study
Pine Creek Reservoir

Prepared for

Walla Walla Basin Watershed Council
Milton-Freewater, Oregon

September 2017

CH2M HILL Engineers, Inc.
Yakima, Washington

Contents

Section Page

Section Page

Acronyms and Abbreviations

AF	acre-foot
AWWA	American Water Works Association
B/C	benefit/cost
cfs	cubic foot per second
CH2M	CH2M Engineers, Inc.
CRBG	Columbia River Basalt Group
GERCC	grout-enriched roller compacted concrete
HDPE	high-density polyethylene
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HGL	hydraulic grade line
kW	kilowatt
kWh	kilowatt-hour
LWWR	Little Walla Walla River
mgd	million gallons per day
mm	millimeter
O&M	Operations and Maintenance
ODFW	Oregon Department of Fish and Wildlife
OM	operational model
OWRD	Oregon Water Resources Department
PCR	Pine Creek Reservoir
PMF	probable maximum flood
POD	point of diversion
Project	Pine Creek Dam and Reservoir Project
PRV	pressure regulating valve
RM	river mile
TDH	total dynamic head
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington State Department of Ecology
WWBWC	Walla Walla Basin Watershed Council
WY	water year
y^3	cubic yard

Introduction

1.1 Background

In June 2005, the U.S. Army Corps of Engineers (USACE) prepared a Draft Concept Study for the Pine Creek Dam and Reservoir Project (Project), located approximately 5 miles west of Milton-Freewater, Oregon (see Appendix A for project elements). The purpose of the off-channel dam and conveyance system is to capture and store winter and spring runoff from the Walla Walla River, and make the water available for irrigation needs later in the spring, summer, and fall. By using the stored water to meet the irrigation demands, more water can be left in the Walla Walla River as instream flows to enhance aquatic life, fish passage, and other ecological values. The Project would increase the total available water supply to the region and change the timing of water deliveries to benefit both agriculture and fish migration in the Walla Walla River. A secondary benefit would include recreational reservoir use.

1.2 Project Approach and Scope

The USACE feasibility study was terminated prior to its completion because of time and funding constraints. This concept study builds upon the prior work by USACE, and supplements, refines, and updates the prior work, with particular emphasis on the following areas:

- Walla Walla River and Pine Creek hydrology data is reviewed, updated, and documented with coordination and assistance of the Walla Walla Basin Watershed Council (WWBWC).
- New Oregon state guidelines for maintaining critical river functions are considered for determining allowable river withdrawals for water storage. The effects of the Project on maintaining and enhancing aquatic life, fish migration, and other ecological values in the river are investigated.
- The reservoir location and size are reviewed and optimized based upon the available water supply and to provide gravity irrigation deliveries.
- A conveyance system is identified to capture and store Walla Walla River water in the reservoir and then distribute the water to key agricultural deliveries.
- Project performance to meet instream flow targets while balancing criteria and water demands will be presented. Other water demands include providing an irrigation water supply that offsets the current policy of 13 cubic feet per second (cfs) of USFWS instream flows to irrigation deliveries. This is a net increase of water currently not available for irrigation.
- Preliminary estimates of construction costs and annual operation and maintenance costs for the selected Project configuration will be updated.
- Next steps for Project implementation will be identified and recommended.

The Pine Creek Reservoir (PCR) project represents an opportunity to address water supply and fish habitat challenges with properly-planned, multi-purpose conveyance and storage facilities that benefit multiple stakeholders in the Walla Walla River basin.

The scope of work for this study and the report presented herein cover the following:

- Establish Evaluation Parameters (Project Criteria)
- Water Supply Strategy
- Conceptual Project Layout
- Project Operation Model

- Estimating Project Costs
- Recommendations for Next Steps

1.3 Acknowledgements

The study was performed under and in coordination with the WWBWC. CH2M would like to recognize the support given by Brian Walcott and Steven Patten of the WWBWC in executing this work. CH2M would also like to acknowledge the technical expertise provided by Steve Tatro and Bill Harrison in developing the dam concept.

SECTION 2

Water Supply Strategy

2.1 General Approach

An early assessment of the potential affects to aquatic resources was necessary because of Oregon State Senate Bill 839. In 2013, the Oregon Senate directed the State Water Commission to establish rules regarding the seasonal diversion of flows using a consistent methodology, which ended up translating into a maximum diversion rate from a river. In 2014, the Commission published a Draft Report entitled "A Proposed Percent of Flow, an Approach for Water Storage Projects in Oregon" (OSWC, 2014). The report determined that if any project proposed to divert more than 15 percent of the flow of a river, an evaluation of specific resources would be required to justify the increased rate, and show that aquatic resources, including the physical functions of the channel, would be protected to a level acceptable by the state. The Commission issued a set of evaluation parameters and assessment guidelines including the following:

Hydrology:

- Natural and altered hydrographs
- Recurrence intervals
- Exceedance probabilities

Hydraulics:

- Modeled depths, velocities
- Wetted area
- Modeled water surface elevations

Physical Processes:

- Channel flushing, maintenance, forming flows
- Floodplain/habitat connectivity flows
- Sediment transport flows

Biology:

- Migration triggers
- Spawning, incubation
- Juvenile rearing
- Adult fish passage

This section presents the modeled water data at this preliminary stage of the Project development. Although CH2M Engineers, Inc., (CH2M) cannot provide information on all of the "guideline" subjects listed, nor every recommended analysis in the proposed guideline, we can provide direction to where the data is pointing, relative to potential impacts of a number of these subjects. We were able to pair the flow and hydraulic data with flow and habitat relationship information available from several studies completed in the Walla Walla River below the diversion over the past 17 years (such as instream flow studies and flood reoccurrence calculations). This effort provides river-specific correlations between Project flows and aquatic resources, rather than relying solely on theoretical comparisons and predictions. Although the flows are predicted only at the diversion, we have made some attempt to quantify what these flows would result in downstream. However, to have the type of assessment that would be accurate enough for agency review at this point is beyond the scope of this work. Planning for a new project that will divert a relatively substantial amount of water in an already impacted stream requires a substantial amount of study, coordination, and negotiation with all players involved and is, more often than not, a very lengthy process. Barring that, because the hydrologists and engineers were able to incorporate a relatively large amount of the necessary modeling inputs, constraints, operational rules, etc., we have a high level of confidence that this analysis can present the direction and relative magnitude of the potential effects (both beneficial and detrimental) that the proposed Project would have on aquatic resources and give the Council several more pieces of useful information in helping to determine whether to move forward the proposed Project.

In general, because the proposed Project diverts water in the late-fall through spring months when river flow rates are highest and less important to the fish of biggest management concern (salmonids), the Project benefits are expected to substantially outweigh any presumed negative impacts. In addition, because the Project would replace the perceived need by some individuals to irrigate outside of the irrigation season (or extra diversion during the irrigation season), the flows will be more predictable and more controllable at the diversion point. The lack of storage, and therefore predictability, often leads to less than optimal irrigation practices exacerbating any ongoing detrimental instream flow conditions.

2.2 Hydrology

For this analysis, the hydrology of interest comprises the Walla Walla River's historical flows upstream of the point of diversion (POD). Historical flows are used to perform the operational modeling for the reservoir, to develop the altered hydrographs downstream of the POD. The altered hydrographs demonstrate the performance of the Project to meet instream flow objectives while at the same time meeting the flow demands. See Section 4, Project Operation Model, in this document, for details on the operational criteria and project performance. The altered hydrographs are also presented in this section for accessing the impacts of the diversions to fill the reservoir.

The hydrology or historical flows were developed and provided by the Walla Walla Basin Watershed Council (WWBWC). See Appendix B, Hydrology for details on the flow analysis performed. Table 2-1 and Table 2-2 are a summary of flow statistics developed for the Walla Walla River upstream and the historic downstream of the POD. Table 2-3 is the flow statistics for Pine Creek developed from the analysis.

Table 2-1. Flow Statistics for the Estimated Natural Flows of the Walla Walla River Upstream of Cemetery Bridge (WY 1970 to 2016)

	Min	Median	Max	Average	90%	75%	50%	25%	10%
7-Oct	80	116	193	116	96	104	116	128	138
21-Oct	82	123	551	129	100	109	123	140	158
7-Nov	97	141	919	161	109	121	141	167	216
21-Nov	93	166	2758	214	113	131	166	231	340
7-Dec	97	181	1740	242	126	145	181	268	410
21-Dec	88	182	2135	234	122	142	182	253	411
7-Jan	79	206	2273	269	126	157	206	320	462
21-Jan	105	216	2074	302	135	170	216	321	546
7-Feb	103	226	3251	298	143	181	226	333	493
21-Feb	101	283	2385	333	171	216	283	373	532
7-Mar	131	331	1454	369	203	238	331	452	583

Table 2-1. Flow Statistics for the Estimated Natural Flows of the Walla Walla River Upstream of Cemetery Bridge (WY 1970 to 2016)

21-Mar	132	354	1278	388	212	263	354	458	599
7-Apr	163	380	1986	435	256	310	380	507	685
21-Apr	150	404	1727	448	270	323	404	515	698
7-May	129	383	1402	439	223	273	383	556	740
21-May	106	309	1216	347	154	213	309	458	592
7-Jun	100	209	1313	253	126	161	209	285	424
21-Jun	96	151	701	171	113	130	151	185	255
7-Jul	90	129	293	134	105	114	129	145	173
21-Jul	89	120	205	122	101	108	120	131	151
7-Aug	82	116	169	118	98	107	116	127	145
21-Aug	80	114	220	116	96	104	114	122	139
7-Sep	79	114	163	114	94	103	114	121	139
21-Sep	28	114	486	115	93	102	114	124	141

Table 2-2. Flow Statistics for the Estimated Historic Flows of the Walla Walla River Downstream of Cemetery Bridge (WY 1970 to 2016)

	Min	**Median**	**Max**	**Average**	**90%**	**75%**	**50%**	**25%**	**10%**
7-Oct	-15	38	137	39	10	22	38	52	67
21-Oct	-19	46	478	52	10	27	46	71	99
7-Nov	-7	77	881	99	30	52	77	118	169
21-Nov	33	131	2747	178	64	95	131	204	304
7-Dec	70	161	1720	219	102	124	161	242	391
21-Dec	39	167	2132	217	101	128	167	238	389
7-Jan	0	192	2254	255	115	146	192	305	446
21-Jan	0	205	2074	288	124	159	205	311	542
7-Feb	0	220	3251	288	133	175	220	323	488
21-Feb	86	274	2384	322	143	204	274	363	522
7-Mar	29	310	1453	345	161	221	310	428	574
21-Mar	29	304	1226	333	138	200	304	409	567
7-Apr	47	296	1909	353	168	221	296	434	601
21-Apr	39	322	1698	361	162	233	322	426	613
7-May	18	293	1325	337	96	163	293	445	653

Table 2-2. Flow Statistics for the Estimated Historic Flows of the Walla Walla River Downstream of Cemetery Bridge (WY 1970 to 2016)

21-May	-1	201	1140	231	38	78	201	338	475
7-Jun	-11	90	1216	139	31	47	90	172	298
21-Jun	0	50	565	67	24	36	50	70	126
7-Jul	5	48	182	49	23	35	48	57	67
21-Jul	7	52	141	50	30	42	52	58	65
7-Aug	12	51	108	50	31	41	51	57	65
21-Aug	4	47	118	45	27	35	47	54	59
7-Sep	4	40	110	40	19	29	40	50	57
21-Sep	-13	38	398	40	17	27	38	49	61

Table 2-3. Flow Statistics for the Estimated Historic Flows of Pine Creek (WY 1970 to 2016)
[TO BE PROVIDED BY WWBWC]

2.3 Fisheries Impacts

2.3.1 Fish Habitat in the Walla Walla River

There are differing opinions on limiting factors on the distribution and abundance of steelhead, bull trout, and Chinook Salmon.

- Most sources recognize sediment loading as an issue. However, for Steelhead this is not an issue below river mile (RM) 24, as it is assumed they do not spawn there. Chinook Salmon may be impacted in the lowermost reaches. Bull trout occur throughout the system, although timing differs in available documents. Bull trout are considered to spawn in headwater reaches of the North and South Forks of the Walla Walla River, and its tributaries such as Mill Creek and Touchet River (USFWS, 2002).
- River temperatures are recognized as a limiting factor at the POD (RM 45.9) and downstream during the summer and fall rearing season for all fish species.
- Pool habitat is limited. Pool habitat is probably most important in overwintering fish below the POD.
- The amount of fine sediment below the POD probably limits interstitial spaces for overwintering fish (boulder/cobble crevices filled). High velocities occur in the 2-mile river reach downstream of the POD due to the channelizing constraints of the USACE-constructed levee. These higher velocities prevent settling of fine sediments. Baseball sized cobbles predominate in this reach. Downstream of the USACE levee, there is an increase in finer sediment. Food production is not mentioned but is probably impacted by the number of fines in the system. Overall number of macroinvertebrates and forage fish most likely out-produce any limitations for the number of fish present.

2.3.2 Impacts to the Natural Hydrograph

The assessment of hydrographs is usually done with the intention of looking for shifts in peak and low flows. Shifts in peak flows are important because both upstream and downstream migrating fish use changes in flow as one of several signals to migrate. Changing upstream migration timing can affect egg and fry survival as eggs may be spawned too early, and thus possibly hatch too early into conditions too cold to survive. Alternatively, if fish spawn too late, the eggs may hatch later in the spring during higher flow conditions, such as spring runoff, which would be detrimental to their survival due to poor swimming ability.

Overall, the resulting hydrographs indicate that the peak flows will be slightly reduced but there will be no shift in the peak flow occurrences from historic conditions, only a relatively small reduction in their magnitude. Therefore, the potential impact on the timing of upstream migrating adult fish and downstream migrating juvenile fish is not expected to be affected to any measurable degree. The reduction in magnitude of the peak flows is most likely small enough that it would have no effect on the migration of fish. Flow rates would not be reduced to the point that they would impede passage.

2.3.3 Impacts to the Exceedence Flows

2.3.3.1 Winter holding habitat in pools

Winter salmonids, as well as almost all inland freshwater fish, show a decline in metabolism, feeding, and general activity at lower water temperatures. Numerous studies have documented the fall/winter movement of trout into sheltered, interstitial spaces among cobble and boulder substrates (Bjornn, 1971; Baltz et al., 1991; Brown and Mackay, 1995; Campbell and Neuner, 1985; and Heggenes et al., 1993). For larger fish (greater than 250 millimeters [mm]), which cannot practically enter substrate crevices, Heggenes et al. (1993) found that the fish tended to aggregate in deep, slow pools.

During winter nights, trout tend to come out of their substrate refuge areas and position themselves on the streambed (Campbell and Neuner, 1985; Heggenes et al., 1993). Campbell and Neuner (1985) and Don Chapman Consultants (1989) observed steelhead moving inshore to shallower water at night, but only into well-protected, low-velocity areas. Salmonids tend to be lethargic and feed only passively and minimally at night. Their lack of aggressive behavior in the winter suggests that social interactions may not be an important factor regulating populations at this time of the year (in contrast to summer). Instead, they may be more regulated by the physical structure of the stream (Heggenes et al., 1993).

This inactivity by salmonids in the winter is a key component in assessing the relative magnitude of potential affects that the Project may have on fish overwintering in the Walla Walla River below the POD. As stated, the Project proposes to divert water mostly during the late-fall and winter. This is corresponding to the period of known low activity by salmonids. Therefore, any reduction in habitat due to lower flows would be tempered by the fact that the fish are most likely to stay in a relatively small area with minimal movements. Therefore, less physical habitat would be needed during the winter compared to the summer.

While an extensive review and characterization of winter habitat reduction is beyond the scope of this task, there are some quick checks available to determine how much habitat might be changed by the proposed reduction in flows. Pools are often a preferred over-wintering habitat by larger fish. Pool habitat is one type of habitat whose cross-sectional area and wetted width are often the least effected by reductions in flow due to the physical properties that make a pool. Typically, the banks of pool habitat are more vertical than others, thus making their wetted width less susceptible to big changes in conjunction with changes in flow. Practitioners of instream flow studies and fish habitat modeling are well aware of this, as pool habitat is often not included when calculating wetted width characteristics within a study reach. As flow rates decline, pool velocities also decline. As far as fish are concerned, lower velocity is beneficial because it requires less metabolic output. It is our conclusion that the changes in flow will not reduce the amount of pool habitat to the degree that it would have any effect on fish using pools as wintering habitat.

2.3.3.2 Channel Wetted Width.

An instream flow study was conducted in the Walla Walla River in 2000-2001 by the Washington State Department of Ecology (WDOE) and Washington Department of Fish and Wildlife (WDFW) (WDOE, 2002). The study was conducted downstream of the Project POD in a 6-mile reach below the State of Washington Highway 125 bridge, just north of the Washington/Oregon state line. The study included 24 total transects split evenly between three study locations. The report provides general relationships between flow and channel wetted width for the three study reaches. One relationship is developed for each study reach.

CH2M used the WDOE study to investigate potential changes in streambed habitat related to the Project. Changes to the wetted width of the stream were estimated using historic and Project flow rates (exceedance values) and known relationships between flow and wetted width in the WDOE study. It is important to note that this comparison is based on a couple of relationships between flow and habitat at a specific site just downstream from the POD. It would not be valid to apply these relationships throughout the entire Walla Walla River downstream from the POD as the channel shape varies. Nevertheless, we believe the wetted width/flow relationship from the 2002 study provides a relatively good surrogate for non-pool habitat of the lower 40 miles of river as the overall habitat of the lower river is relatively consistent. Lower reaches of the river do not include vastly different habitat types such as cascades or large and deep pool complexes. More studies or comparisons of existing data would need to be made to reach definitive conclusions on the Project's potential effect throughout the entire lower river.

To find the maximum change in wetted width that could occur under the proposed Project, we found the largest changes in flow between Project and historic flows as depicted in the exceedance flow tables (Tables 2.1a through 2.1c in Appendix C). We then applied these maximum flow reductions to the wetted width relationships developed by WDOE (2002) during their instream flow study below the POD. The maximum flow reductions and the resulting wetted width reduction are shown in Table 2.5 in Appendix C.

Wetted width reductions ranged from 0.6 feet to 5.2 feet. The average reduction of the wetted width for each exceedance scenario over the three study reaches is 1.9, 2.9, 1.9, and 1.7 feet, respectively, for 90 percent exceedance through 25 percent exceedance. The wetted width relationships for all three study reaches did not encompass the high levels of flows that occurred in the 10 percent exceedance scenario. Overall these results show a 5 percent or less reduction in wetted width when Project flows would be at their maximum difference from historic conditions. Given that fish need less physical space during the winter, these predicted examples of maximum changes in the wetted widths of non-pool habitat are small enough that we would not expect any effect on fish overwintering outside of pool habitat.

2.3.3.3 Summer Rearing Flows

Water temperature is currently one important limiting factor for rearing fish in the Walla Walla River, especially in the summer and early-to-mid fall months. Under historic conditions (Table 2.1a in Appendix C) and "wet" water-years (10 percent exceedance), the flows at the POD are less than 67 cfs. Flow rates drop below 20 cfs in the dry water-years (90 percent exceedance). On individual days (or a series of days, the river actually dries up at the POD. Since the year 2001, the Walla Walla River has not dried up at any location in Oregon. Prior to 2001, the river would go dry in the summer about 2.5 miles downstream of the POD. Under Project conditions (Table 2.1b in Appendix C), a low of 74 cfs is predicted to be maintained at the POD except under extreme conditions when the flow would drop to a minimum of 34 cfs. At no time would the Project result in the river being completely dewatered. Higher summer flow rates would result in more physical habitat being present and would undoubtedly have a desirable affect in cooling water temperatures further downstream relative to present conditions. While we can't predict the changes in water temperature, our experience in running sensitivity analyses in water temperature modeling has found that increasing water quantity with cooler water results in lower water temperatures farther downstream in a system.

2.3.3.4 Potential of Redd (egg) Desiccation

The potential for egg desiccation is a concern when projects divert water after fish spawning. The proposed Project will divert water after almost all salmonids have spawned in the river. However, if we look back at the predicated changes in wetted width it shows that the stream channel will only be slightly affected by the reduction of winter flows (about 5 percent or less). Therefore, only fish that spawn at the margins of the stream would be at risk for egg desiccation. The salmonids in the Walla Walla River are rather large species and would require gravel and small boulder substrate with interstitial flow to keep the eggs oxygenated. This type of habitat does not exist along the margins in the river. In addition, spawning below the POD does not appear to be prevalent for any of the salmonid species in the system per our review of the literature. Therefore, it is our opinion that salmonid egg desiccation from winter diversion at the POD is not a significant issue.

2.4 Geomorphology

This section evaluates the flows required for channel maintenance in the Walla Walla River in the reach near the POD at Cemetery Bridge and estimates impacts to bed material movement, between the POD and the downstream railroad bridge, resulting from the Project.

Extensive characterization of the channel bed substrate, bedload transport, channel geometry, and hydraulic conditions is required to establish the magnitude and duration of flows which form and maintain the channel, as well as provide floodplain connectivity. Some of these field data, such as pebble counts, have been collected at different locations and times in the project reach (Patten, 2014). However, there is sufficient variability in the resulting riverbed grain size distributions that additional data collection near the POD will be required for more definitive analyses.

As a preliminary analysis, prior work performed by GeoEngineers (2012) is utilized to estimate the effects of the Project on bed material movement. A Hydrologic Engineering Center's River Analysis System (HEC-RAS) model of a larger portion of the river, and a pebble count near the POD were used as part of statistical analysis that considers uncertainty in key variables such as discharge and grain size. Results should be considered preliminary and updated with site-specific field data.

In Robison (2007), the Oregon Department of Fish and Wildlife (ODFW) states that the objective of channel maintenance flows is “to provide conditions conducive to creating or maintaining stream morphology and habitat,” and this guidance document focuses on methods of estimating streamflow conditions where bed material movement occurs.

This impacts assessment follows the methodology of Robison (2007), by calculating the “trigger” flow, the discharge at which gravel and larger size bed material begins to move and calculating the critical discharge required to generate the critical shear stress to initiate movement of bed material, specifically the median particle size, d50.

2.4.1 Estimation of the Trigger Flow for Channel Bed Movement

Robison (2007) specifies two discharge values that mobilize the channel bed: the threshold flow and the trigger flow. The threshold flow is the discharge that initiates Phase 1 transport, or movement of sand and fine gravel, while trigger flows initiate Phase 2 transport, or movement of larger gravels. Both discharge values are less than the effective discharge, which does the most geomorphic work of channel shaping over a period of years.

The guidance document suggests that for Oregon gravel bed streams, a two-year recurrence interval flood (Q2) is the likely trigger flow. The Q2 discharge is a common proxy for the bank-full flow, the flow where the channel banks of an alluvial river are overtopped and inundation of the floodplain begins. The trigger flow is commonly associated with the bank-full flow. However, the recurrence interval of bank-full flow was found to vary between one to three years for rivers in the Pacific Northwest (Castro and Jackson, 2001), with an average recurrence interval of 1.4 years.

This preliminary analysis relies upon a flood frequency analysis performed by GeoEngineers (2012), where peak flows were estimated at the Washington/Oregon state line. This analysis used historic flow records from three gaging stations within the watershed to develop a record of instantaneous peak flows at the state line. This record was then analyzed using a log Pearson Type III distribution to estimate the magnitude and recurrence interval of peak flows. Using this method, the estimated Q1.5 and Q2 flow rates at the Washington/Oregon state line are 2160 and 2618 cfs, respectively. The watershed area at this point is 200.6 square miles.

Given the watershed area (159.6 square miles) at the POD, and using the proportional area method, the estimated Q1.5 and Q2 flow rates at the POD are 1,719 and 2,083 cfs, respectively. By ODFW guidance, the trigger flow at the POD is estimated to be 2,083 cfs, and flows exceeding this value should be maintained in-stream.

However, the basis of the estimation of threshold and trigger flows, (GeoEngineers, 2012), is fundamentally different from the hydrologic analysis performed as part of the Project. The GeoEngineers (2012) analysis uses a statistical skew as opposed to a weighted skew, resulting in larger peak discharges. For example, estimated peak discharges of the 10- to 500-year recurrence interval were higher than those of six other hydrologic studies performed in the area. A refined analysis will include an evaluation of the most appropriate hydrologic analysis for the estimation of threshold and trigger flows.

2.4.2 Estimation of the Critical Shear Stress

Per ODFW guidance, a second component of establishing when bed material is in motion requires estimating the critical shear stress to initiate movement of a given grain size. The grain size distribution of the channel bed material is commonly characterized using a series of Wolman pebble counts (Wolman, 1954). The distribution of grain sizes of each count results in an estimated d50, or median grain size particle. This grain size is associated with the dominant size of the bed material and used in calculations of incipient motion. The shear stress required to initiate movement of this grain size is the critical shear stress.

For this analysis, the results of a single pebble count performed by GeoEngineers (2012) in the vicinity of the project reach was used. The d50 (59 mm) of the pebble count performed near the Frasier Farmstead Museum in Milton-Freewater, Oregon, (RM 46.1) was used to estimate the critical shear stress.

The critical shear stress was calculated using the Shield's equation

$$\tau_C^* = \frac{\tau_C}{(s-1)\varphi g D}$$

Where:
τ_C^*= critical value of Shield's number, dimensionless
τ_C= critical shear stress
ϕ= density of water
g = gravitational parameter
D = grain size
s = ratio of sediment density to water density
The dimensionless Shield's number is a function of dimensionless viscosity and varies from roughly 0.03 to 0.045 for fully turbulent flow for unisize grains. The Shield's number can also be impacted by mixtures of grain sizes. As little as 10 percent sand composition in the bed material can lower the Shield's number resulting in mobilization at lower flows (Wilcock et al., 2001). Consequently, characterization of the

grain size distribution of the bed material is critical to establishing a critical shear stress for initiation of movement.

Using a dimensionless Shield's number of 0.045 and a grain size of 59 mm, the critical shear stress was calculated to be approximately 0.9 psf.

2.4.3 Shear Stress Downstream of the POD

The discharge which generates the critical shear stress is the critical discharge. Using the HEC-RAS model developed by GeoEngineers, the critical discharge corresponding to the critical shear stress was identified using rating curves of shear stress versus discharge for cross-sections between Cemetery bridge (RM 45.9) and the downstream railroad bridge at Nursery Bridge Road (RM 44.7). These ratings curves are included in Appendix C.

There is great variability between critical discharge values at the cross-sections. Fourteen of the 25 cross sections exceed 0.9 psf at flows less than 800 cfs, and most of these cross sections occur nearer to the downstream railroad bridge at Nursery Bridge Road (RM 44.7). The critical discharge of the remaining eleven cross-sections varies from 950-2350 cfs. The average critical discharge of these eleven cross sections is approximately 1755 cfs. Using the results of the HEC-RAS model, the critical discharge to mobilize the d50 grain size is roughly 1755 cfs. This discharge is slightly higher than the estimated Q1.5 at the POD of 1719 cfs.

2.4.4 Monte Carlo Analysis of Critical Discharge

There is great uncertainty in the parameters used to calculate shear stress including Shield's number, d50 grain size, and hydraulic roughness or Manning's "n" value. A statistical approach to this problem is to create a statistical distribution of each variable and calculate a population of critical discharge values, resulting in a mean and standard deviation of the calculated population of values.

The estimated mean and standard deviation of the Shields parameter, d50 grain size, and Manning's "n" were used as statistical inputs to a Monte Carlo simulation. The simulation also uses specified values of slope and channel top width as a power law function of discharge. The spreadsheet-enabled macro makes 1000 calculations of the critical discharge required to move the median particle (d50) by randomly selecting values of Shield's number, d50 grain size, and Manning's "n" from the user-specified statistical distributions for each calculation. A histogram of the resulting sample population shows that for the estimated statistical distributions, the mean critical discharge is 1983 cfs with a standard deviation of 274 cfs. This value is slightly higher than the average of the Q1.5 and Q2 values at the POD (1901 cfs). See Figure 2-1.

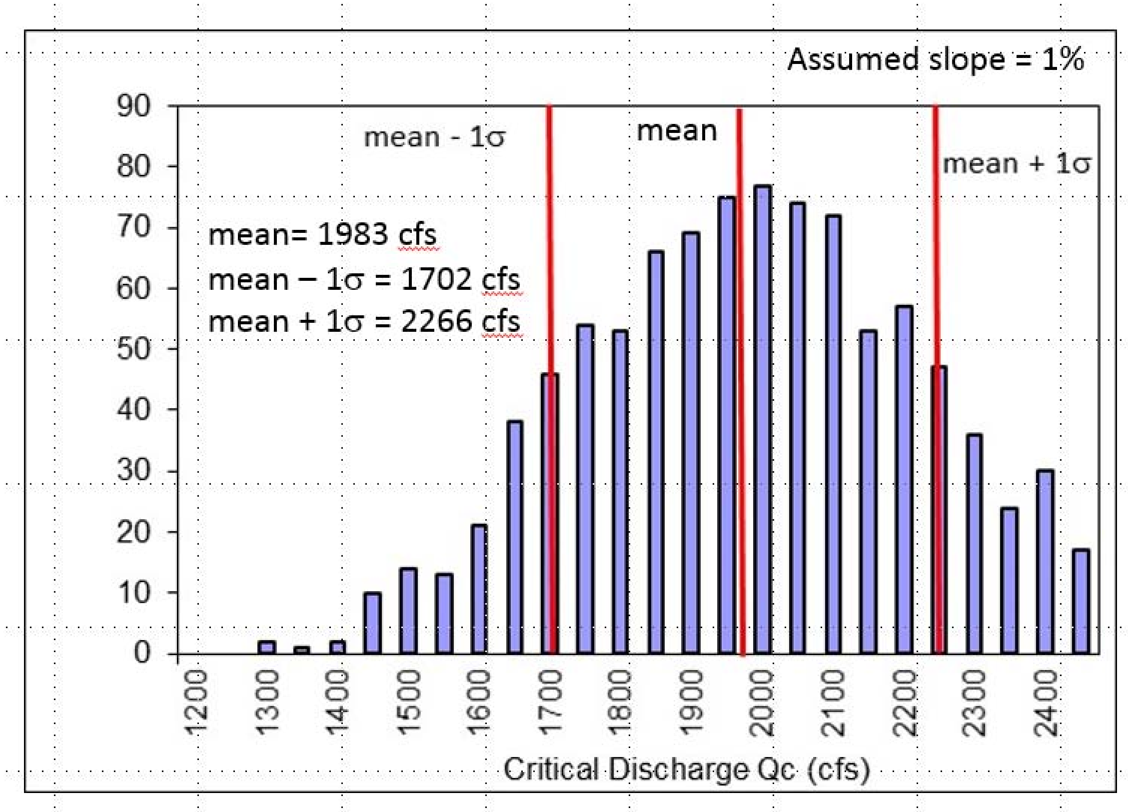


Figure 2-1. Histogram of Statistically Generated Population of Critical Discharge Values

2.4.5 Impacts of Flow Diversion on Bed Material Mobilization

Results of this analyses are summarized below:

- Bed material may be mobilized as early as about 1700 cfs, but significant bed material movement such as Phase 2 transport may occur at somewhat higher discharge values.
- Bed material appears to be mobilized at flood recurrence intervals less than Q2.
- The critical discharge at which shear stress exceeds 0.9 psf varies from 250 -2350 cfs between the POD and the downstream railroad bridge indicating areas of erosion and deposition.

Given these results, impacts to channel maintenance flows can summarized as follows:

- Planned diversion operation drops to 20 cfs intake when discharge exceeds 2000 cfs. This results in a loss of 1 percent or less of in-stream flow when Phase 2 transport is occurring. This means that most larger grain sizes will have the opportunity for mobilization, unimpeded by diversion operation and the effective discharge should be relatively unimpacted.
- Planned diversion operation intakes 25-30 percent of streamflow up to 2000 cfs. This operation defers when channel bed movement begins to a higher recurrence interval. This means that Phase 1 transport will be impacted, frequency of bed mobilization may decrease and the duration of movement may decrease. The decreased duration might not be significant over the full range of channel maintenance flows.
- Planned diversion operation ceases for 18 hours when discharge exceeds 1000 cfs. This facilitates flushing of fine sediments, and enables Phase 1 transport to occur.

These cursory analyses indicate that impacts on channel maintaining and forming flows resulting from flow diversion are likely to have minimal to moderate impact. However, there is great variability in sediment initiation in the reach between Cemetery Bridge and the downstream railroad bridge, and the critical discharge to initiate movement of the d50 grain size is dependent on highly uncertain variables.

The proposed diversion may have limited impacts on channel maintenance and forming flows, but better characterization of the bed material and hydraulic conditions is required to refine the anticipated impacts.

Project Layout

3.1 Existing Facilities and Operations

Currently the existing irrigation system consists of a screened river diversion near Cemetery Bridge that supplies water to the FROG using the Little Walla Walla River for conveyance. The FROG is the irrigation distribution point for the Walla Walla River Irrigation District and Hudson Bay Irrigation District. The diversion flows have historically ranged from a high of approximately 125 cfs in the spring to an average of approximately 65 cfs thru the summer. Diversions have historical been year-round, with the exception of a couple weeks in February for maintenance on the screened river diversion. The average historical annual volume for the diversion from 2002 thru 2016 is approximately 42,600 acre feet.

3.2 Proposed Dam and Reservoir

3.2.1 Siting of Dam

As described in the Walla Walla River Basin Feasibility Study (USACE, 2005), up to 45 sites have been evaluated over the years in the basin. After an initial screening evaluation, the number of sites under consideration reduced to seven. Criteria used in the initial screening included foundation suitability, structural configuration, local impacts, Endangered Species Act factors and other relevant factors.

During a second round of screening, the seven sites were evaluated using criteria such as basis of size, landowner issues, potential benefits, water capacity, and water availability. The outcome of the secondary screening was selection of two dam sites located relatively close to each other on Pine Creek near Umapine, Oregon.

The topography of the reservoir areas in Pine Creek Valley is described as follows:

> *Pine Creek valley is located in the foothills of the Blue Mountains. These foothills form the southern edge of the Walla Walla Basin. The right or northeast side of Pine Creek valley is much steeper than the left or southwest side. In general, the right side of the valley has an overall slope of about 10 to 15 percent. The gentle slope to the southwest forms the toe of the foothills leading up to a plateau*. (USACE, 2005).

The lower downstream site (Site 1 in USACE, 2005) is located near where Pine Creek exits the valley. The upper site (Site 2 in USACE. 2005) is located about 1.5 miles upstream of the lower site. The two dam sites are shown in Figure A-1 in Appendix A. In their study, the USACE assumed a similar dam configuration at both sites, with the structure being assumed an earth dam with a silt core, filter/drains and shells of earth (soil) materials. The USACE also considered a roller-compacted concrete (RCC) dam as an alternative to the earth dam.

The advantages and disadvantages of the two sites were considered and evaluated in this study. The conclusion was to focus efforts on the upper site for the dam location given the multiple advantages over the lower site. The following subsections describe some criteria and considerations considered for the comparison.

3.2.1.1 Hydraulic Considerations

For the lower site, the elevation band of the active storage requires pumping for all the irrigation deliveries. This would require the construction of a pump station and would involve a substantial annual power cost. The estimated annual power costs were approximately $570,000 (USACE, 2010) making the site cost prohibitive primarily for annual energy costs. The elevation band for the upper site is more suitable for both gravity filling and emptying. Minimal pumping is required, with most years not requiring any pumping.

3.2.1.2 Geologic Considerations

Whereas the subsurface conditions are generally similar for both sites as described in Section 3.1.1, there is a difference when it comes to the configuration of the right abutment. The right abutment of the lower dam is a narrow ridge about 500 feet across. This relatively narrow ridge could potentially result in relatively high hydraulic gradients and increased risk of excessive seepage and internal erosion at the abutment. At the upper dam, the proposed right abutment is much wider so seepage through this abutment should not be a problem.

3.2.1.3 Dam and Reservoir Size

The lower site is limited by the local topography for a total storage volume of approximately 28,000 acre feet. A larger dam and greater storage volume can potentially be built at the upper site making it a preferred location for evaluating alternative sizes.

3.2.2 Subsurface Conditions

Our understanding of the subsurface conditions is based on the geotechnical information provided in the Walla Walla River Basin Feasibility Study (USACE, 2010).

The area of the site is in the Columbia Plateau Geologic Province. Bedrock underlying both sites consists of basalt of the Columbia River Basalt Group (CRBG), with overburden consisting of (1) silt and (2) sandy gravel and cobbles (USACE, 2005). The basalt rock is generally fine to medium grained and is pillowed in many places. The material is generally “massive to fractured and may be highly vesicular to pillowed in outcrop.”

There are two separate silt deposits, the Touchet Beds and a loessal deposit, called Palouse Loess. The USACE considered the silt to have similar engineering characteristics: “the material will stand vertical in cut, has poor permeability, and is marginally compressible when dry to highly compressible when saturated. Sandy gravel and cobbles is encountered on the site both as a loose stream deposit along Pine Creek and as an underlying consolidated “cemented gravel.”

The USACE noted that the bedrock was considered a suitable foundation for a dam at both sites, and that the site has “similar geology, seismology, groundwater, and material haul distances” (2010). Most fractures (discontinuities) in the rock appeared to be horizontal and were generally tight and rough. The rock also generally had low permeability, although zones of high permeability were encountered that would require a grouting program. The USACE recommended a single row grout curtain on 10-foot centers for feasibility design purposes, but in this study, we assumed a two-row grout curtain with grout holes spaced at 7.5 feet, which is more consistent with the current state of practice.

Actual subsurface conditions can have a considerable impact on construction cost, so it is important that a geotechnical investigation be performed in the next design phase to be able to make a more meaningful assessment of the feasibility of dam construction at this site.

3.2.3 Dam Hydrology

The majority of the water entering the proposed PCR will be diverted and conveyed from the Walla Walla River. Normal inflow from the Pine Creek drainage basin does provide a water supply source, but is relatively minor and ephemeral in nature (see Section 2.2, Hydrology). As it relates to dam hydrology, the potential for flood flow, however, could be significant. The basin encompasses approximately 50.9 square miles upstream of the proposed dam site on the north slope of the Blue Mountains. The watershed elevations range from approximately 4,300 feet to approximately 800 feet at the location of the proposed dam.

The proposed size and likely hazard classification lead to the recommendation of a design flood equal to the probable maximum flood (PMF) for the proposed dam and storage reservoir. The PMF is the flood that can be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible for a given location. Previous efforts by USACE to derive the peak PMF inflow of 15,200 cfs was used to size the spillway and stilling basin.

3.2.4 Hazard Classification

The degree of conservatism that are adopted for a dam project typically depends on the consequences of a dam breach. Where a dam breach could result in downstream flooding that could result in a loss of life, the design events/loadings adopted for the project are typically very conservative. On the other hand, if there is no or very low risk to the public, the design level is typically lower and primarily based on economic considerations including project replacement and disruption of operations.

Under the State of Oregon Administrative Dam Safety Rules (Chapter 690, Division 20, Rule 690-020-0100), dams are assigned a hazard rating of low, significant or high. The State of Oregonutilizes dam breach and inundation analyses to determine the hazard rating. The following criteria are used to determine the hazard rating:

> *(a) An inundation depth of flowing water of at least two feet over the finished floors of dwellings, other frequently occupied buildings, or road surfaces where a vehicle is likely to be present establishes a "high hazard" rating.*
>
> *(b) Any inundation depth of water over the floorboards of structural buildings establishes a "significant hazard" rating.*
>
> *(c) For other roads and vulnerable utilities, an inundation depth of two feet or evidence of depth and velocity capable of creating damage establishes a "significant hazard" rating.*
>
> *(d) Wherever heavy recreational or other frequent use occurs downstream a "high hazard" rating shall be established to prevent probable loss of life. Such designation shall not depend on the presence of downstream infrastructure.*
>
> *(e) For water depths close to those listed in the subsections (a) and (c), the Department may also consider water velocity in its determination of hazard rating.*

No breach analyses and inundation mapping was performed for this concept study. Based on criterion (a) and CH2M's understanding of downstream development, it is assumed that the proposed Pine Creek Dam will be assigned a high hazard rating.

The State of Oregon has a number of regulations pertaining to a high hazard dam including requirements for design flood and earthquake, spillway, and low level outlet.

3.2.5 Dam Type Alternatives Comparison and Selection

Two dam types have been considered as part of this concept study: (1) An earthfill dam and (2) a roller-compacted concrete (RCC) gravity dam. Given the apparent lack of clay materials near the site, the RCC dam was selected as the preferred concept for this study.

Although silt appears to be plentiful near the site, and it is common and acceptable practice to use a silt core in lower head dams (less than 100 feet high), such a core becomes an unacceptable risk for large dams. Silt has very low resistance to internal erosion, and some dambreak disasters including Teton dam failure and the emergency incident at Fontenelle dam are associated with the use of silt material as a seepage barrier. Given the relatively steep abutments, narrow valley, and large dam height, the likelihood for cracks in an earthfill dam would be high. A total reliance on filters must be assumed in such a scenario, violating the principle of having multiple lines of defense.

Given these considerations, it was deemed appropriate to conservatively assume an RCC dam concept for this study. In a next phase, a more rigorous comparison and optimization evaluation should be performed to select the most appropriate and cost-effective dam type for the site. Besides the two dam types originally identified by the USACE and considered in this study, other dam types such as earth core and a concrete face rockfill dams, should also be considered.

3.2.6 Roller Compacted Concrete (RCC) Gravity Dam and Spillway

Dam Description

The RCC dam alternative is a concrete gravity dam that relies on the weight of the concrete to withstand the forces imposed on the dam. RCC is defined as a relatively dry, no-slump consistency concrete that is typically delivered by dump trucks or conveyors, spread by bulldozers in thin horizontal lifts (about 12 inches) and compacted by vibratory rollers similar to the placement methods used to construct earth dams (Bass, 1991), see Figure 3-1. RCC has essentially the same ingredients as conventional concrete, but in different ratios and commonly with partial substitution of fly ash for Portland cement. It is placed at a much dryer moisture content compared to conventional concrete.

Figure 3-1. Typical RCC Dam Construction
Pine Creek Dam Concept Study

The biggest advantage of RCC versus conventional concrete is its much lower unit price per cubic yard. That is because RCC uses less cement, requires less formwork and is placed with conventional earthwork techniques in essentially a continuous operation. The unit price for RCC is generally about $80 to $130, whereas conventional concrete can be double that amount. Compared to most conventional earth dams, an RCC dam can be constructed in less time. Another advantage is that relatively little damage occurs if the dam is overtopped during construction.

Dam Foundation: An alluvial layer that is assumed to be about 15 to 20 feet thick overlies basalt bedrock in the valley floor. The RCC dam concept assumed that all the alluvium in the valley floor would be excavated such that the entire dam is founded on hard, slightly weathered to fresh basalt rock at an assumed depth of about 50 feet below the existing ground surface. The excavation will thus include removal of the upper 30 feet of basalt rock, which is expected to be highly to completely weathered.

At the abutments, an excavation depth of about 15 feet was assumed. This includes removal of a thin layer (5 feet) of soil that overlies the basalt, as well as about 10 feet of weathered basalt rock.

Note that the RCC dam will require a higher quality foundation rock than the conditions required for an earthfill, or earth core or concrete face rockfill dam. This is because the RCC dam is more rigid and less tolerable to deformations and the hydraulic gradient in the foundation is higher because the dam is narrower.

Dam Geometry: The RCC cross section assumed for this preliminary comparative analysis was determined based on review of existing RCC dams constructed on good quality rock foundations. The dam shown has a vertical upstream face, a crest that is 20 feet wide and a downstream slope of 0.8H:1V (see Figure A-6 in Appendix A), which is similar to the photo of the dam shown in Figure 3-1. If sliding or seepage (and internal erosion of rock discontinuities) as a result of weathered and weak layers or seams in the foundation is a concern, the slopes will become flatter. For example, Duck River Dam in Alabama (Riker et al. 2016) was recently constructed with a 0.1H:1V upstream slope and a 1H:1V downstream slope because of the presence of shale layers and clay and coal seams in the foundation. As shown in Figure A-6 in Appendix A, steps that are 4 feet high and 3.2 feet wide were assumed for the downstream slope, which is a typical step configuration.

Gallery: Figure A-6 in Appendix A shows a drainage and inspection gallery that will be large enough (10-foot wide and 12-foot high) to allow installation of the grout curtain from the gallery. Various drains will extend to the gallery including monolith joint drains, face drains, and foundation drains. The gallery will not be horizontal but will step up in the abutments to roughly follow the top of the excavated foundation surface (see Figure A-5 in Appendix A).

Foundation grouting: Although grouting from the gallery tends to be more difficult and expensive, it can be a useful option if the construction schedule is tight. The option will remove grouting from the critical path and allow RCC placement to proceed while concurrently grouting from the gallery without impacting RCC operations. Another benefit of grouting from the gallery is that the RCC placed below the gallery floor acts as a thick grout cap facilitating relatively high grouting pressures, and this a more effective grouting job in the upper foundation layers.

To estimate the cost of the foundation grouting, a two-row grout curtain with maximum grout hole lengths of 200 feet was assumed (with shorter holes in the abutments). It was further assumed that the final pattern hole spacing is 10 feet, but with some areas of tertiary grouting with a final hole spacing of 5 feet. Two rows of blanket grout holes extending to a depth of 25 feet into the foundation and spaced at 7.5 feet were included in the concept.

Facing Systems: Some early RCC dams experienced unacceptable seepage flows through the horizontal lift joints and vertical cracks. Since then, monoliths joints have been used to control/prevent vertical cracks and upstream facing systems consisting of conventional concrete, precast concrete, geomembranes, and grout-enriched roller compacted concrete (GERCC) have been used to reduce seepage along lift lines. Another, less robust, approach is to treat the upstream zone (say 8 feet wide) of lift joints with bedding mortar to reduce leakage along the joints. Facing systems have also been used to improve durability and appearance of the downstream RCC steps especially in the spillway section.

Facing systems have not been evaluated for this high-level concept study. In this study, for cost-estimating purposes, a GERCC facing system was assumed.

Spillway Description: The unique benefit of an RCC dam is that a portion of it can serve as the spillway by adding a spillway crest at the top and training walls for the crest and chute. Given this, a relatively long spillway can be constructed economically with the main limitation being to transition the flow at the downstream side to a smaller channel. For this dam, the length proposed for the spillway is 165 feet. Using a longer spillway provides the benefit of reduced surcharge on the spillway crest to pass the PMF flow, which reduces the freeboard and dam height requirements. The additional length will also reduce the unit discharge and potentially reduce the size of the stilling basin required to dissipate the energy.

The spillway crest assumed is an ogee shape that is hydraulically efficient to pass flow. The shape of an ogee spillway is affected by the relative head, approach depth, approach velocity, and slope of upstream face. Determining the values for each of the parameter is dictated by both hydraulic design requirements and geometric requirements specific to the project. For this level of design, the peak outflow for the PMF was assumed with no flood routing of the PMF and no freeboard. The result is a surcharge of 8 feet to pass the PMF. The height of the dam was then set with surcharge requirement of only 8 feet with no residual freeboard since no flood routing was performed and an RCC structure can be overtopped for limited time periods without risk of breaching the dam. Under this configuration, the dam has a composite spillway. The spillway entrained in the chute serves as a primary spillway to pass the smaller, more frequent floods and the remaining dam crest acts as an emergency spillway for the extreme events. The Oregon Water Resources Department (OWRD) requires 1 foot of freeboard while passing the design flood on a high hazard dam. Future designs should perform flood routing and have additional coordination to determine if the assumption of no freeboard or further cost saving by having the RCC dam act as an emergency spillway with overtopping is acceptable.

The spillway chute is a “stepped chute” due to the construction methods for an RCC dam. The result is a flow regime over the steps that changes primarily with changes in the unit discharge or flow per unit length over the spillway. The length and drop of the individual steps and number of sequential steps also influence the flow regime. The flow regime varies from nappe flow at low unit discharges to skimming flow at high discharges. Nappe flow is characterized by a succession of free-fall jets from the vertical drop from a step that then impacts the horizontal run of the next step that is followed by a hydraulic jump before cascading off the end of the step to repeat the sequence. Most or all of the energy is dissipated before reaching the toe of the dam. As the unit discharge increases, the flow regime transitions to skimming flow where the water flows as a coherent stream skimming over the steps with residual energy reaching the bottom of the spillway chute requiring a stilling basin. The stilling basin was sized assuming skimming flow down the spillway chute for half the PMF. If a full PMF flow occurred, the hydraulic jump would likely sweep from the basin causing some downstream erosion, but not compromise the safety of the dam. The hydraulic design methods for the stilling basin follow guidelines for a U.S. Bureau of Reclamation (USBR) Type III basin. Multiple layers of RCC will be placed to form the stilling basin. It is assumed that the upper 2 or 3 layers will consist of RCC with greater cement content or conventional concrete to attain greater strength levels. Higher strength seems prudent given the flow conditions in the basin and the potential erosion that can occur. As is done with most stilling basins, uplift relief drains will be drilled through the RCC slab into the foundation rock. The structural design of the stilling basin slab will determine the extent of anchoring required to resist the remaining uplift force. Retaining walls of significant height are required for the stilling basin.

Outlet Works Description: The requirements for the outlet works is to pass normal stream flows while also having the capacity required by the OWRD of releasing the top 5 feet in 5 days. A relatively large fixed-cone valve with a baffled and smaller plunger valve are used to meet the high and low flow requirements and for developing costs. The flow from the valves is discharged into the stilling basin allowing for transition of flows into the natural downstream channel without requiring any additional erosion protection. The pipe extends upstream under the dam to a gated intake structure with a trash rack. The wall thickness under the dam is thicker than required for pressure and loading conditions, but was considered appropriate given the critical nature of the pipeline and its position beneath the dam.

3.2.7 Study Assumptions

The preliminary concept for the proposed Pine Creek dam was developed from a review of existing information, including geotechnical information provided in the Walla Walla River Basin Feasibility Study (USACE, 2005). There are some limitations and assumptions associated with this preliminary concept study; these are described below. The depth of foundation excavations for the RCC dam is about 50 feet (20 feet of soil and 30 feet of rock) at the valley bottom and 15 feet (5 feet of soil and 10 feet of rock) at the abutments.

- The basalt bedrock is anticipated to be moderately to highly jointed or fractured, such that a rigorous grouting program will be required to improve the foundation. A two-row grout curtain, as well as two rows of blanket grout holes were assumed with a relatively high average grout take of about one sack of cement per lineal foot of grout hole.
- It was assumed that all the RCC aggregate can be processed from a basalt quarry within 1 mile from the dam.
- Groundwater will be higher than the bottom of the excavations, but it can be controlled with typical drainage trenches, and sumps and pumps. No elaborate dewatering system was assumed for this concept study.

3.3 Conveyance and Distribution

The conveyance and distribution portion of the proposed project include the facilities required to transfer water on the Project excluding the dam outlet works. The following components of the conveyance and distribution facilities are described in this section:

- River Intake and Fish Screens
- Main Conveyance Pipeline
- 940 Distribution Pipeline
- Irrigation Turnouts
- Booster Pump Station

The design was limited to only develop a reasonable cost and estimate Project requirements. A brief description as it relates to this analysis for developing reservoir operational rules and developing a conceptual cost estimate for each facility are provided in the following subsections.

3.3.1 River Intake and Fish Screens

The river intake diverts and screens from the Walla Walla River at Cemetery Bridge. The design capacity is 220 cfs, but CH2M understands it does not perform at capacity. The operation and function for the river intake and fish screens becomes more complex with the proposed Project. The following are highlights of additional functions to expand the facility:

- Regulate flow to either or both the Little Walla Walla River (LWWR) and the main conveyance pipeline. Water supply to the LWWR provides direct river flow for irrigation. Flow to the main conveyance pipeline provides for filling the reservoir.
- Secondary screening capacity will provide redundancy for operation, continued operation during normal maintenance of primary screens, and additional capacity when the river flows are high enough allowing for additional flow or filling the reservoir.

- Sediment removal with the addition of a sediment trap to return sediment to the river and reducing maintenance of the piping system with less frequent sediment flushing and physical removal.
- Regulate and measure flows to full design capacity.
- Screens and intake will need to be able to operate under winter conditions near or at design capacity with mitigation measures for cold and ice buildup.

3.3.2 Main Conveyance Pipeline

The main conveyance pipeline extends from the river diversion structure to the bifurcation of the outlet works for the proposed Pine Creek Dam. It is approximately 46,000 feet long (8.7 miles). The pipeline will provide bi-directional flow capability to allow for both filling and draining of the PCR. The pipeline is proposed to be 78-inch diameter. It is expected to be a cement mortar lined and coated welded steel pipe, generally in accordance with American Water Works Association (AWWA) C200. A nominal wall thickness of 5/16-inch was assumed for this analysis. It was nominally sized to limit velocity to less than 4 feet per second at the maximum flow rate. The pipe has been oversized to minimize head loss so that it can operate by gravity both directions. Oversizing will result in low velocities at lower flows and increase the potential for sediment accumulation. The current thoughts are the water has relatively low turbidity when the flow is low. Sediment is also mitigated with allowance for an oversized turnout for flushing at the low spot in the profile and a sediment trap added at the river diversion.

During the filling cycle, it will operate with upstream control at the river diversion. The flow regime will be open channel at the upstream end. A hydraulic jump will occur when the pipeline transitions to full pipe. The hydraulic jump will move up the profile as the reservoir fills and the flows increase. This will require design for air venting and filling without surging. During the draining cycle or conveying water back for irrigation demands, the flow will be controlled at the downstream end at the irrigation turnouts. The pipeline can convey lower design flows to the 940 pipeline for irrigation deliveries in summer and late fall. It can convey to the FROG under gravity flow for higher water levels in the reservoir.

3.3.3 Distribution Pipeline

The main distribution pipeline is called the 940 pipeline because it is nominally at the 940 contour elevation. The 940 contour was chosen because it is where the reservoir can maintain gravity flow and not require pumping for the majority of the water deliveries. It extends from the main conveyance at the 940 contour and extends north and eventually west. It is approximately 10,000 feet long (1.9 miles). The pipeline is proposed to be initially 32-inch diameter and ultimately reduce to 18-inch at the end of the deliveries. It was nominally sized to limit velocity to less than 4.5 feet per second at the maximum flow rate. It is expected to be a relatively lightweight high-density polyethylene (HDPE) pipe, generally in accordance with AWWA C200.

Appurtenant features for the pipeline are expected to be contained within other structures. As such, the only appurtenant features along the pipeline will be the irrigation turnouts.

3.3.4 Booster Pump Station to FROG

The booster pump station is intended to lift water from the 940 bifurcation to the FROG at low reservoir operating water surface elevation conditions. The total dynamic head (TDH) requirement is 25 to 50 feet for flows ranging from 5 to 17 cfs. Typically, there are two options available for providing a wider range of pumping flexibility and performance. The first is throttling the pumps using flow control valves, and the second involves using variable speed pumps. Given that it is anticipated that there will be infrequent use, throttling was assumed due to the least initial cost. Throttling would introduce head loss into the system such that at least 50 feet of TDH can developed at all times. Throttling could be used to achieve any combination of flow and head (reservoir level). The actual control scheme would be developed as part of a more detailed design.

3.3.5 Irrigation Turnouts

Figure A-9 in Appendix A illustrates the locations of the proposed irrigation turnouts. The variable head and flow used for making multiple changes warrants a sophisticated system. The levels of sophistication include:

- A plunger valve that allows for regulating flow over a relatively large range of head variance. It is desirable to have relatively low head loss when the reservoir levels are low and still dissipate energy, and controlling flows when the reservoir is low. An isolation ball valve is also proposed.
- A flow meter that allows for precise measurement of flow.
- Remote operation that is using real time information to make changes given the complexity of having multiple sources of water and limitations of available river flow. Multiple water sources is referring to the potential for direct flow from the river or supply from the reservoir or any combination.

The irrigation turnouts would be in a concrete vault structure containing the isolation and control valves required for flow regulation. The structure is assumed to have a fully removable aluminum cover (insulated) to minimize the depth and associated cost of the facility. This approach eliminates the need for a bridge crane, but requires a portable crane be utilized to install/remove equipment. Since these valves are not expected to require frequent removal and/or replacement, the removable cover system was reasonable. A variety of instruments will be provided to monitor valve position and pressure to modulate the flow control valves to have automated irrigation deliveries.

3.4 Bennington Flow Augmentation Considerations

A brief analysis was performed to determine if Mill Creek flows could be a viable source of water supply for storage to the Pine Creek Reservoir. The following sections briefly describe the analysis.

A pipeline alignment and profile was developed from the existing outlet works of Bennington Dam and connecting to the proposed 940 pipeline (see Figure A-1 in Appendix A). The alignment was such to create a profile that allowed for the pipeline to fill and drain without air blow back or pipe filling transients. The pipeline was sized to provide up to 20 cfs diversion capacity resulting in a 36-inch diameter HDPE pipe. A conceptual cost estimate was prepared for the pipeline and is summarized in Appendix D.

The total capital cost of the Bennington Flow Augmentation is $23,674,000. For more information, see Appendix D.

3.4.1 Mill Creek Diversion Rules

WWBWC provided the rules of operation based on experience with similar projects in Washington State for diverting water from Mill Creek. Our understanding is that the diversions can only occur between December 1 and May 30. Only a fraction (15 to 25 percent) of the flows in excess of the instream flow can be diverted. Table 3-1 compares the instream flow requirement with the calculated average and assumed 20 percent of the incremental average flow above the instream flow requirement. Using the average flows as a comparison, shows that the limitations imposed severely limit the potential for diverting any appreciable quantity of flow.

Table 3-1. Instream Flow Requirements in the State of Washington, Average Flow, and 20 percent of the Average Flow above the Instream Flow for Mill Creek

Time Period	Instream Flow Requirement (cfs)	Average Flow (cfs)	20% of the Difference Between the Instream and Average Flow (cfs)
December 1 to January 31	110	133	5
February 1 to February 28	125	159	7
March 1 to April 30	150	169	4
May 1 to May 31	125	120	0

3.4.2 Operating Model Results

The Mill Creek stream gage was extended using regional stream gages to develop the same 47 years of daily flow record (see Appendix B, Hydrology for details). The purpose was to perform a simulation in the operation model (see Section 4, Operational Model) that included a Mill Creek diversion to better understands the benefits. The rules applied for Mill Creek diversion were to; 1) diverting 20 percent of the Mill Creek flows in excess of the instream flow requirement, 2) limit the flow to 20 cfs. The results for the small reservoir was a reduction in years with summer/fall shortages from 7 years to 5 years and the average shortage per occurrence changing from 3,540 acre-feet (AF) to 3,433 AF.

3.4.3 Conclusion

The conclusion is that the costs far outweigh the benefits, given the diversion restrictions imposed by the state of Washington, which significantly reduce Project water volumes, particularly during dry years. During a dry year, the Mill Creek flows will drop to less than the instream flow requirement and no flow will be available for diversion to Pine Creek. During wet years when flow is available, the Walla Walla River is capable of filling Pine Creek reservoir to capacity.

3.5 Lowden Pipeline Considerations

3.5.1 Purpose

The Lowden Pipeline was investigated as a means of reducing river diversions at the lower end of the Project. The conceptual pipeline alignment and profile are shown on Figure A-1 and Figure A-11 in Appendix A. The pipeline would convey water from the existing irrigation system, across the valley to Lowden's current diversion on the Walla Walla River.

3.5.2 Costs

The conceptual cost estimate of the pipeline is provided in Appendix D. The total capital cost of the Lowden Pipeline is $7,374,000. For more information, see Appendix D.

3.5.3 Benefits

The benefit of providing water to the Lowden diversion was explored with the Confederated Tribes of the Umatilla Indian Reservation to verify the best use of stored water.

Flow delivered through the Lowden Pipeline would not benefit fish migration in the Walla Walla River, because the water is withdrawn from the river and not available to fish. CH2M also determined that hydropower would not be economically feasible unless water was delivered more than 148 days per year (see Section 3.7, Hydropower Considerations for Lowden Pipeline).

3.5.4 Conclusion

The Lowden Pipeline does not warrant further consideration, given the cost of the facility and the fact that there are no significant fisheries or hydropower benefits. The best use of the water is to leave it in the upper end of the Walla Walla River to benefit fish migration, and to develop a means of protecting the water in the State of Washington.

3.6 Hydropower Consideration for Irrigation Deliveries

A reconnaissance-level feasibility assessment of adding hydropower to irrigation deliveries is appropriate because excess hydraulic head (water pressure) may be available at the delivery locations. The objectives of these assessments are: (1) evaluate basic technical feasibility, (2) estimate energy production and order-of-magnitude costs, (3) evaluate simple benefit/cost (B/C) economic feasibility, and (4) identify fatal flaws. The results of this reconnaissance-level feasibility assessment will provide the WWBWC with a basis for a go/no-go decision whether to pursue any of the alternatives further toward final definition and assessment of project feasibility.

3.6.1 Hydropower Assessment Background and Objectives

Many water facility operators have explored the potential opportunities to integrate hydropower generation with their existing liquid process streams, where excess head (or pressure) could be converted to electric energy. Such installations can help achieve sustainability goals, address the rising cost of energy, and capture the energy available in the potential excess head/pressure and flow along a facility's hydraulic profile.

Power output from a hydropower turbine, regardless of size or type, is proportional to flow through the turbine and head (or differential pressure) across the turbine. In principle, low-head/high-flow and high-head/low-flow conditions offer the same power and energy potential. The power formula for a hydraulic turbine-generator is:

$$\text{Power output in kilowatts (kW)} = \frac{\text{Q (cfs) x H (feet) x turbine-generator efficiency}}{11.82}$$

The energy produced over time in kilowatt hours (kWh) equals the average power multiplied by the operating time in hours. Relating this to water conveyance applications, 1 million gallons per day (MGD) equals 1.55 cfs. Generally speaking, turbine equipment designed to utilize large flows under low head is more costly than equipment operating under high head at low flows. Further, turbine performance is generally based on operation under fairly constant head conditions. Operating head variation can result in lower efficiency and limitations in operating range.

There are several critical considerations required for a hydropower generation facility installed in a pipeline designed for purposes other than hydropower generation, including the following:

1. A hydropower generation facility typically requires a means of automatic bypass to ensure continuity in water delivery should the turbine-generator be shut down due to maintenance or emergency. A common bypass feature in a municipal water delivery system includes a pressure regulating valve (PRV) in parallel with a hydropower turbine. In some cases, the PRV is existing and can be utilized in the infrastructure for the hydropower development. In other cases, a new PRV is required as part of the project.

2. Turbine-generators will shut down under a variety of protective and operational conditions. Some, like an electric utility outage, can occur regularly, and are considered part of normal operation. Such shutdown of hydroelectric equipment will result in transient flow conditions. These flow transients will produce surge pressures in both upstream and downstream conveyance features. As such, the capacity of the conveyance system to manage these surge pressures must be considered and should be carefully evaluated during the final feasibility evaluation of a project.
3. Installation of hydroelectric equipment will change the hydraulic profile (or hydraulic grade line [HGL]) by reducing the available pressure (head) in a delivery system. As such, the feasibility of installing hydroelectric equipment typically requires that a reduction in HGL will not adversely affect downstream operations.

Due to the relatively high cost of features associated with hydropower production, such as permitting, utility interconnection, and the modification of the conveyance features necessary to install the turbine, the simple economic feasibility of these installations can be challenging. However, financial or tax incentives, along with broader sustainability goals can strongly influence overall feasibility.

The purpose of this study is to conduct a reconnaissance-level assessment of hydropower feasibility for two alternatives. The evaluation of simple B/C economic feasibility was performed the same way for each alternative evaluated in the study. Money spent or accrued at different times, or over a period of time, must be discounted or escalated to a single point in time in order to be compared properly. For development of the proposed projects, recurring benefits and operation and maintenance (O&M) costs occur throughout the life of the project. To discount these recurring costs and benefits to a present value in today's dollars, a present worth factor was applied.

The assessment utilizes an analysis period of 20 years and a discount rate of 1 percent. As a result of projecting a 3 percent annual increase in the effective rate paid for energy, a different present worth factor was applied to benefits versus costs. For benefits, a geometric gradient series present worth factor was applied to energy savings to account for both the time value of money and the escalating rate paid for energy. For costs, a uniform present worth factor was applied to reoccurring O&M and debt payments (if applicable) to account for the time value of money. The formulas used to calculate these different present worth factors are shown in Figure 3-2.

Geometric Gradient Series Present Worth Factor applied to Benefits = $\dfrac{1-\left\{\dfrac{1+g}{1+i}\right\}^n}{i-g}$	Uniform Present Worth Factor applied to Costs = $\dfrac{\{1+i\}^n-1}{i(1+i)^n}$
Where:	Where:
g = 3 percent (increase in energy value)	i = 1 percent (discount rate)
i = 1 percent (discount rate)	n = 20 (period in years)
n = 20 (period in years)	

Figure 3-2. Net Present Worth Factor Calculations

For the purposes of this reconnaissance-level analysis, all costs and benefits were applied in today's dollars, neglecting any escalation between today and a future on-line date.

3.6.2 Hydrology and Net Head

Historical daily flow and head data from the 47 years of operational model scenarios were analyzed. The data indicated a high variance in the flow rate and the available head for hydropower generation, with flows at 0 cfs for nearly 60 percent of the year. Two assessments were performed; one based on the large reservoir alternative, and one based on the small reservoir alternative. Both alternatives utilize the same flow data, but the net head available for hydropower generation differs between the two.

3.6.3 Energy Production

Average annual energy production was estimated for each alternative using the historical data with a spreadsheet-type analysis. Turbine/generator equipment have restrictions on the range of head and flow at which they can operate. The constraints listed in Table 3-2 were applied to the analysis. If the flow rate or net head for a particular day was outside the constrained range, it was assumed the generating equipment would not run and there would be zero energy production that day. For the analysis, a flat 80 percent efficiency was considered.

Table 3-2. Constraints

Assumptions	Large Res. Alternative	Small Res. Alternative
Maximum flow rate	55 cfs	55 cfs
Minimum flow rate	27.5 cfs	27.5 cfs
Maximum net head	104 feet	70 feet
Minimum net head	41.6 feet	28 feet
Turbine/Generator Capacity	387 kW	261 kW

The resulting estimated annual energy production for each alternative is as follows:

Alternative 1 – Large Reservoir: 555,000 kWh

Alternative 2 – Small Reservoir: 250,000 kWh.

3.6.4 Order-of-Magnitude Cost

A generic order-of-magnitude cost estimate for the hydropower installation was calculated. In this go/no-go feasibility analysis a detailed cost estimate was not prepared. Instead, a generalized rule of thumb estimate based on the equipment capacity was calculated. For equipment of this size, facility costs can be estimated between $4,000 and $5,000 per kW. This estimate does not include costs associated with the conduit upstream or downstream of the plant, or the bypass valve.

Considering a plant capacity of 387 kW and 261 kW for the large reservoir and small reservoir alternatives respectively, the total development cost for each alternative is as follows:

Alternative 1 – Large Reservoir: $1,800,000

Alternative 2 – Small Reservoir: $1,300,000

3.6.5 Economic Feasibility

The conventional economic feasibility of developing a hydroelectric project is determined by comparing the present value of benefits (that is, revenue from the sale of energy) with the present value of costs (the capital cost for development, O&M costs, etc.). This comparison can take the form of the net present value (benefits minus costs) or B/C ratio. A simple financial-economic analysis, illustrating the costs, benefits and economic feasibility of developing each site is provided.

3.6.5.1 Costs

The following two cost elements have been estimated for the development of each alternative:

- Alternative 1 – Large Reservoir:
  - Total development cost: $1,800,000
  - Annual O&M cost (estimated at 2 percent of capital cost): $36,000
- Alternative 2 – Small Reservoir:
  - Total development cost: $1,300,000
  - Annual O&M cost: $26,000

3.6.5.2 Benefits

Based on similar projects, the value of the energy is approximately $0.08 per kWh. The energy values are estimated to increase at a rate of 3 percent annually. Combining these rates with average annual energy production, the projected annual revenue or benefit from the proposed installation during the first year of operation would be:

- Alternative 1 – Large Reservoir: $8,000
- Alternative 2 – Small Reservoir: -$6,000

3.6.5.3 Present Value of Benefits and Costs

Based on the methodology outlined in the *Hydropower Assessment Background and Objectives* section, Tables 3-3 and 3-4 summarize the economic feasibility of developing each alternative. In this analysis, it is assumed that debt is not incurred for development of the project. The financial economic analysis summarized below reflects 100 percent up-front payment of total development costs.

Table 3-3. B/C Ratio for Hydropower Development for Alternative 1

Item	Value
Discount Rate	1%
Energy Value Escalation per Year	3%
Analysis Period (years)	20
Uniform Series Present Worth Factor	18.05
Geometric Gradient Series Present Worth Factor	24.01
Present Value Non-Financial Costs	$650,000
Present Value Initial Investment	$1,800,000
Total Present Value of Costs	$2,500,000
Total Present Value of Revenue/Benefit	$1,100,000
Net Present Value	**-$1,400,000**
Overall Present Value B/C Ratio	**0.43**

Table 3-4. B/C Ratio for Hydropower Development for Alternative 2

Item	Value
Discount Rate	1%
Energy Value Escalation per Year	3%
Analysis Period (years)	20
Uniform Series Present Worth Factor	18.05
Geometric Gradient Series Present Worth Factor	24.01
Present Value Non-Financial Costs	$500,000
Present Value Initial Investment	$1,300,000
Total Present Value of Costs	$1,800,000
Total Present Value of Revenue/Benefit	$500,000
Net Present Value	**-$1,300,000**
Overall Present Value B/C Ratio	**0.27**

3.6.6 Conclusions

The objectives of these assessments are (1) evaluate basic technical feasibility, (2) estimate energy production and order-of-magnitude costs, (3) evaluate simple B/C economic feasibility, and (4) identify fatal flaws.

The technical feasibility evaluation determined that a 387-kW turbine generator unit could efficiently capture the available head and flow for the large reservoir alternative. Likewise, a 261-kW turbine generator unit could efficiently capture the available head and flow for the small reservoir alternative.

Average annual energy production was estimated to be 555,000 kWh with an estimated order-of-magnitude cost of $1,800,000 for the large reservoir alternative. The average annual energy production for the small reservoir alternative was estimated to be 250,000 kWh with an estimated order-of-magnitude cost of $1,300,000.

A simple economic evaluation resulted in a benefit/cost ratio of 0.43 for the large reservoir alternative and 0.27 for the small reservoir alternative. For a project to be considered financially feasible, the B/C ratio should be 1.0 or higher.

This assessment concludes that a small hydroelectric turbine/generator is not economically feasible for either the large reservoir alternative or the small reservoir alternative. It is estimated that the fatal flaw associated with this concept is based on an annual average flow curve which estimates little to no running water about 60 percent of the year. It is recommended that no further investigation of hydropower be developed for either alternative.

3.7 Hydropower Consideration for Lowden Pipeline

Annual flow and head data was not available for the assessment of hydropower feasibility for the Lowden Pipeline option, so an estimate was prepared based on a constantly available head and flow rate. Considering a constant flow rate of 20 cfs and a constant net head of 140 feet, a hydropower unit with a capacity of 190 kW would need to run 148 days out of the year to be measured financially feasible. These results are based on the same economic parameters used in the assessment of hydropower on the irrigation delivery system. Refer to Section 4.5, Lowden Pipeline Considerations for the conclusion of considering this pipeline and the role of hydropower.

3.8 Relocate River Intake Considerations

3.8.1 Objectives

The objective of this analysis was to determine if it is beneficial to have an intake located further upstream on the Walla Walla River. There are two primary perceived benefits that warrant additional investigation. The perceived benefit is that more flow can be captured from the Walla Walla River if the flow capacity of the main conveyance pipeline is not limited. The other perceived benefit is that pumping for water deliveries can be eliminated.

3.8.2 New Location Upstream

The proposed new location is approximately 1.9 miles upstream of Cemetery Bridge in the vicinity of the existing Zell irrigation diversion and the roughened riffle at Lampson (see Figure A-1 in Appendix A). The elevation of the new location for the river intake is 1200 feet. The existing river intake is located at approximately elevation 1065. The 78-inch diameter main conveyance pipeline is extended upstream from Cemetery Bridge. A conceptual cost estimate was prepared for the pipeline and the new river intake. The costs for the river intake were estimated by escalating costs from similar fish screen projects. A summary of the cost is provided in Appendix D.

Total capital cost of the pipeline, river diversion, fish screen, and trenchless river crossing is $29,694,000. For more information, see Appendix D.

3.8.3 Unrestricted Flow of Main Conveyance

To determine the benefit, the operational model simulated operations with the river intake at the new location. The simulation was performed for both the small and large reservoir to determine the additional annual volume diverted to the reservoir. The results are presented in Table 3-5.

Table 3-5. Comparing the Volume of Walla River Diverted to Pine Creek Reservoir for the Cemetery POD Instream with a Proposed Upstream Intake

Scenario	**Average Annual Volume Diverted to Reservoir**	
	Small Reservoir	**Large Reservoir**
Relocated Upstream	11,575 AF	12,059 AF
Existing (Cemetery Bridge)	11,540 AF	11,900 AF
Difference	+35 AF	+159 AF

3.8.4 Eliminate Pumping

To eliminate pumping and deliver water by gravity to the FROG at all reservoir water levels, the conservation pool elevation must be equal to the FROG elevation of 987 feet, plus a friction head loss allowance in the delivery pipeline. To accomplish this, the conservation pool would be approximately elevation 995 feet with a volume of 19,500 AF. The dam height would be approximately 175 high with no active storage. The active storage of the small dam would reduce from 26,600 AF to 13,600 AF. The active storage of the large dam would reduce from 39,300 AF to 26,300 AF.

It is not feasible to relocate the dam further upstream, as the steep topography of Pine Creek Drainage would significantly reduce the storage capacity. For example, moving the dam location upstream to save 20 feet of dam height decrease the length of the reservoir at high water level from approximately 8,700 feet to 6,400 feet and the storage would reduce by approximately 25 percent.

3.8.5 Conclusion

Moving the river intake upstream provides no appreciable benefits, while increasing costs and introducing a new obstacle on the Walla Walla River for upstream fish migration. For an estimated cost of $29,694,000, the upstream river diversion increases the average yield for the small reservoir by 35 AF and the average yield for the large reservoir by 159 AF. The unit costs are $848,400 and $186,800 per acre foot for the small and large reservoirs, respectively.

It is not possible to eliminate pumping with the smaller dam, because the active storage would not be sufficient to meet the Project objectives. For the large dam, the active storage capacity is the same as the small dam plus pumping. The capital cost difference between the small dam and large dam is approximately $38,870,000, which would eliminate the booster pump station cost of $2,200,00 and a $4,000 electric bill approximately 1 of every 5 years.

3.9 Dry Creek Water Supply Considerations

3.9.1 Dry Creek Hydrology

The stream gage data for upper Dry Creek is limited to a period of approximately water year (WY) 1966 to WY 1974. With no overlap of other gages, the record cannot be extended with confidence. The 8 years of record was used to develop the daily flows during the storage diversion period from November 1 to May 31. Oregon's incremental flow methodology was applied using a factor of 0.3 for storage diversions. Figure 3-3 shows the flow exceedance for the 8 years of record during the storage diversion period. A reduced exceedance curve that is factored by 0.3 is also shown to represent the potential flow available for storage.

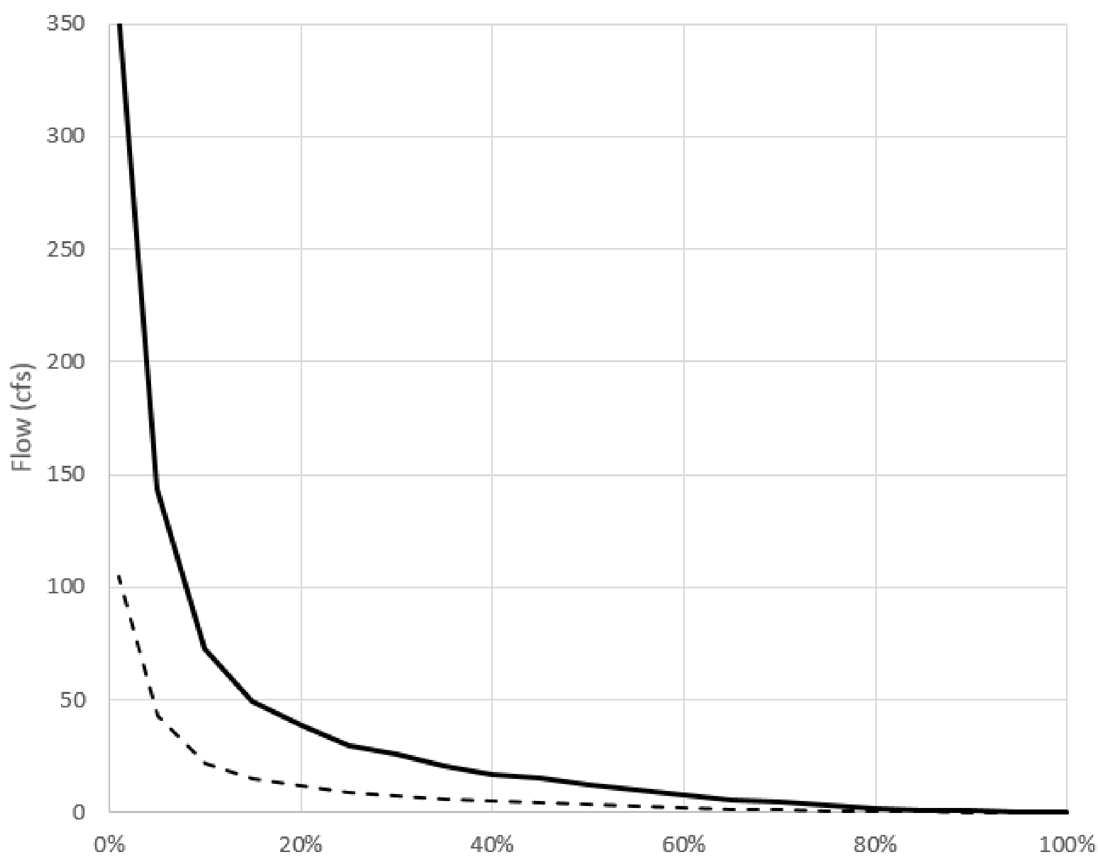


Figure 3-3. Dry Creek Daily Flow Exceedance and Factored Flow Exceedance Curves during the Storage Diversion Period for the 8-Year Record at the Weston Gage

3.9.2 Pipeline and Screened Diversion

A pipeline alignment was developed by finding a starting elevation of approximately 1060 to ensure gravity flow for filling the reservoir. The alignment then followed the drainage until it intersects with the proposed main conveyance pipeline. The result is a pipeline that is approximately 2.7 miles long. An 18-inch diameter HDPE pipeline was assumed to provide a flow capacity of approximately 8.4 cfs which corresponds to the 25 percent flow exceedance. A conceptual cost estimate was prepared for the pipeline and the screened diversion. The costs for the screened diversion was estimated with escalated costs from similar fish screen projects. A summary of the cost is provided in Appendix D.

The total capital cost of the Dry Creek water supply is $2,334,000. For more information, see Appendix D.

3.9.3 Supply to Pine Creek Reservoir

An estimate for the annual flow volume is shown in Table 3-6.

Table 3-6. Estimated Diversion Volume from Dry Creek for Pine Creek Reservoir

Water Year	Estimated Diversion Volume (AF)
1966	997
1967	1670
1968	802
1969	2339
1970	2039
1971	1755
1972	2517
1973	960
Average	1635

3.9.4 Conclusion

For an estimated capital cost of $2,334,000 and average yield of 1,635 AF, the estimated unit cost per AF is $1,400. Given the costs per AF for the proposed Project, Dry Creek should be investigated further as an alternative to improve the reliability and yield of the Project.

3.10 Columbia River Exchange Considerations

The Columbia River Exchange is a project scenario for pumping flows from the Columbia River. The scenario would have a pipeline extending to the FROG with a minimum hydraulic grade line of 987. The booster pump station is designed for increasing the TDH by 50 feet at 17 cfs which is sufficient to fill the reservoir. For dry years when additional storage volume is desired in the reservoir, an additional 1,000 AF per month in the winter could be stored with no increase in capital cost. Increasing the size of the pump station would proportionally increase the potential storage volume.

SECTION 4

Project Operation Model

4.1 General Description

CH2M developed an operational model (OM) for this Project. The objective of the OM is to optimize Project facilities' sizes, capacities, and costs, given the available water supply, to meet water delivery objectives and instream flow targets. The primary outcome of interest is maintaining the instream flow targets in the Walla Walla River. The OM needs to assimilate both regulation, or policy, and physical processes that will dictate its operation.

The best representation of the future water supply for this Project is based on actual historical flow records near the Project. To simulate both the quantity and temporal distribution of flow, the OM uses 47 years of daily historical water supply data to make day-by-day adjustments and simulate proposed Project operations. Refer to Section 3 for additional information on the hydrology used to develop the water supply.

The reservoir operation criteria and parameters of interest often become complicated with site and project specific needs making it difficult to use general programs. General programs often compromise the simulation by approximating with pre- and possibly post- processing the information making a general model inefficient and potentially less accurate. For the Pine Creek reservoir operation model, a custom spreadsheet model was developed so project-specific criteria and parameters could be efficiently evaluated. The efficiencies gained allowed multiple iterations to be performed while working closely with the WWBWC to refine assumptions with a better end-product. The following sections present a narrative on criteria and parameters assumed or calculated in the operation model followed by the results of reservoir performance or yield for a given size and configuration of the project.

4.2 Project Operations Criteria and Parameters

Developing an OM requires that it assimilate both the regulation and physical process that will dictate its operation so the results best represent the potential of the project. Developing the simulations required either estimating with calculations or making assumptions using judgement and experience. The following sections are criteria and parameters used in the OM.

4.2.1 General Reservoir Parameters

Reservoir Stage-Area-Storage The stage versus area relationship is used to calculate the potential storage using the local topography. The information was used from the initial USACE study and verified with an independent evaluation. The independent evaluation was performed using a digital elevation model from the U.S. Geological Survey (USGS) topographic mapping. The results were similar with the USACE information being slightly more conservative (less volume relative to stage).

Evaporation A daily estimate of evaporation was used from the initial USACE study. The USACE study used historical weather data from the Pendleton, Oregon airport to determine monthly average pan evaporation less precipitation. Only 75 percent of the pan evaporation was used to account for the difference of a relatively large water mass.

Seepage The seepage was estimated at an average of 1.8 cfs for the given type of dam, dam height, foundation conditions, and experience with similar projects. It was assumed that the seepage was lost from the system. Though most of the seepage will be recaptured in the dam drainage system and available downstream in Pine Creek to satisfy environmental flows and water rights.

Conservation Pool The assumed elevation of the conservation pool is at elevation 945 with a storage volume of approximately 6,500 AF and dam height of 120 feet. The elevation was driven by locating the elevation band for the active storage that was a compromise of filling the reservoir by gravity flow while also minimizing the need for pumping when delivering the water.

4.2.2 Flow Demands

Flow demands describe or determine how the available water supply is used. Typical flow demands include seepage, irrigation deliveries, and instream flows. Table 4-1 provides a summary of the water demands by priority. The OM assumes the first priority is to satisfy the protected instream water, then upstream and east side irrigation diversions, the irrigation demand is satisfied at the FROG so direct flows need to divert 10 percent above the irrigation demand.

Table 4-1. Operational Model Flow Demand Priorities

Priority	Water Demand Entity	Description
1	Protected Instream Water Right	*[Need definition from WWBWC]*
2	U.S. Fish and Wildlife Service (USFWS) Agreed Flows	*[Need definition from WWBWC]*
3	Irrigation Demand Upstream of Cemetery Bridge and	Consists of multiple irrigation diversions including Zell, Spence, Dorothy, and others
	East Side Irrigation Demand	Diversion is at Nursery Bridge
4	Cemetery Bridge Irrigation Demand	The demand adds the seepage losses from the Little Walla Walla River.
5	Confederated Tribes of the Umatilla Indian Reservation Targets below Nursery Bridge	If available, reservoir storage water is used to meet higher-priority water demands so that this is achieved.
6	70 percent of Upstream River Flows	Based upon the assumption that up to 30 percent of the natural river flows can be diverted for reservoir storage.
7	Reservoir Filling	Limited to the reservoir filling period.

Instream Flow Target The following table provides the instream flow targets located downstream of Nursery Bridge. To achieve the flow target below Nursery Bridge, additional flow needs to be left instream at Cemetery Bridge to compensate for irrigation deliveries to Eastside at Nursery Bridge and for seepage in the Walla Walla River.

Table 4-2. Instream Flow Target below Nursery Bridge and the Required Flow Cemetery Bridge

Time Period	Flow below Nursery Bridge (cfs)	Flow at Cemetery Bridge (cfs) [a]
April 1 to June 15	150 cfs	167 to 169 cfs
June 16 to June 30	100 cfs	114 cfs
July 1 to November 30	65 cfs	70 to 75 cfs

[a] Flow includes Eastside Irrigation (1 to 5 cfs) and seepage in the Walla Walla River (5 to 15 cfs) that vary during the year.

USFWS Flows The USFWS flows are the results of a policy enforced to provide additional instream flows at Cemetery Bridge. The following table provides the instream flow requirement. The OM does not include the requirement when calculating irrigation deliveries while reservoir storage is available. It is included when reservoir storage is depleted and irrigation deliveries are reduced to current policy.

Table 4-3. USFWS Instream Flow Required at Cemetery Bridge

Time Period	Flow below Nursery Bridge (cfs)
Jan 1 to June 30	15 cfs
July 1 to December 31	13 cfs

[a] Flow includes Eastside Irrigation (1 to 5 cfs) and seepage in the Walla Walla River (5 to 15 cfs) that vary during the year.

Irrigation Demands for the Upper Walla Walla River The irrigation demands consist of three assumed diversions. The principle irrigation demand is at the Cemetery Bridge POD consisting of Walla Walla River Irrigation District, Hudson Bay Irrigation District, and a small miscellaneous irrigation diversion. A senior water right exists upstream of the Cemetery Bridge POD. East Side Irrigation is another senior water right. East Side is downstream of the Cemetery Bridge POD at Nursery Bridge. The quantity and temporal distribution of the irrigation demands are shown in Table 4-4.

Table 4-4. Irrigation Demands in the Upper Walla Walla River (Oregon Side)

Time Period	Upstream of the LWWR POD	East Side at Nursery Bridge	Walla Walla River Irrigation District		Hudson Bay Irrigation District		Misc. Irrigation	Total	
			FROG	<940	FROG	<940	FROG	Flow (cfs)	Volume (Acre-Feet)
OCT		4	10	20	2	48	0.6	85	5,225
NOV			6	13	0	31		50	2,975
DEC			4	9	0	27		40	2,459
JAN			4	9	0	7		20	1,229
FEB			4	8	0	0 [b]		12	666
MAR		1	6	14	0	8 [b]		29	1,783
APR		2	6	13	0	21		42	2,499
MAY	10	4	15	35	2	48		114	7,008
JUN	20	4	15	35	3	67	0.6	145	8,626
JUL	20	5	15	35	2	23	0.6	101	6,209
AUG	20	5	15	35	1	9	0.6	86	5,287
SEP	10	4	14	31	2	18	0.6	80	4,759
TOTAL									**48,724**

The irrigation demands are limited to what would be available with direct flow.

Aquifer Recharge Demands The current practice for aquifer recharge was assumed to not be occurring for future operations with a reservoir.

Pine Creek Demands The water right on Pine Creek was assumed to be 60 cfs from May 1 thru October 31. An environmental flow of 5 cfs was assumed for the remaining part of the year. Any Pine Creek flows in excess of these values was stored in the reservoir. The water right and environmental flow was limited by the flow in Pine Creek with no reservoir water used.

Walla Walla River Seepage between Cemetery Bridge and Nursery Bridge Estimates of river seepage typical vary seasonally and with flow or wetted perimeter. A set value was provided by WWBWC from historical observations; this aligns with the flow targets below Nursery Bridge. Walla Walla River seepage between Cemetery (POD) and Nursery Bridge is 5 cfs except in the spring. Spring seepage is 10 and 15 cfs for Confederated Tribes of the Umatilla Indian Reservation targets of 100 and 150 cfs targets, respectively. Different river seepage estimates were provided late in the modeling effort as it was determined to maintain these initial assumptions.

Little Walla Walla River Seepage The direct flow diverted from the Walla Walla River was assumed to operate as it does currently and utilize the Little Walla Walla River for conveyance to the FROG. WWBWC provided an estimate of 10 percent seepage loss for this relatively short reach (approximately 1.6 miles). Though it is regulated and screened at the POD and used primarily for irrigation conveyance, it is assumed from historic experiences that the State of Oregon regards the Little Walla Walla River as a natural stream and will not allow for any piping to reduce losses.

Diversion Efficiency A diversion efficiency of 100 percent was assumed for being able to divert flows and make available to either the reservoir or satisfy irrigation demands. Typically, there is diversion efficiency assumed for not being able to capture the water for a project. For this project, the objectives of instream flow targets would benefit from any inefficiencies. There will also be both pluses and minuses of diversion flows in daily operations that would likely balance out.

Reservoir Outflow Operational Efficiency An efficiency of 97 percent was assumed for making irrigation deliveries from the reservoir. There will be some water lost or mismanaged in operating the reservoir. These are minimized with a closed system (piped) and multiple flow measurements to remotely regulate irrigation turnouts.

4.2.3 Water Supply (In Flow or Water Source to Meet Demand)

Walla Walla River Historical flow measurements were used to develop a continuous daily record for 47 years from October 1, 1969, to September 30, 2016. The total is the sum of multiple gages, with some data gaps filled by correlations with other gages. See Section 2.2, Hydrology for details.

Pine Creek Similar to the Walla Walla River, historical flow measurements were used to develop a continuous daily record for 47 years from October 1, 1969, to September 30, 2016. Data gaps and extension of records were determined with correlations of other gages. See Section 2.2 for details on the hydrology.

Reservoir Filling Period The State of Oregon regulations limit the period of filling the reservoir from November 1 in the late fall through the winter to May 31 the following spring (information provided by WWBWC). The dates for filling typical do not restrict the ability to fill the reservoir as the dates align with when the water supply is available given the instream flow targets and irrigation demands.

Direct Flow The water directly available from the Walla Walla River for meeting irrigation demands after satisfying the instream flow targets, similar to current operations. The water is diverted using river intake and conveyed to the FROG for distribution in the Little Walla Walla River. Direct flow will have the seepage loss of the Little Walla Walla River. The remaining irrigation demand is satisfied using the reservoir.

River Intake Capacity The assumed river intake capacity is 270 cfs. The existing river intake has a design capacity of 220 cfs that will require modifications to the downstream control to achieve the capacity. An additional 50 cfs of secondary capacity was assumed to be added to the existing river intake to capture higher river flows and provide redundant capacity for maintenance or break downs of the primary screens.

Conveyance Capacity for Filling The conveyance capacity for filling the reservoir changes with the water surface rising and falling in the reservoir (see Figure A-10 in Appendix A). The capacity is limited by the river diversion screens (270 cfs) when the reservoir water level is near empty. It then switches over to downstream control as water level approaches approximately 950. The capacity continues to reduce to approximately 155 cfs and 95 cfs for when the small and large reservoirs are full, respectively. The pipe is over-sized to reduce the restriction.

Conveyance Capacity for Irrigation Deliveries The conveyance capacity for providing irrigation deliveries changes with the water surface rising and falling in the reservoir (see Figure A-10 in Appendix A). The capacity to deliver to the FROG is high (>150 cfs) when the reservoir water level is high. It can deliver 150 cfs to the FROG until the water level approaches approximately 1020 and 150 cfs to the 940 pipeline until the water level is approximately 970. The capacity continues to reduce to approximately 60 cfs at the conservation pool of 945. The pipe is oversized to reduce the restriction and minimize pumping.

First Flush River Diversions It is assumed that there is no water being diverted when the Walla Walla River flows increase rapidly for 18 hours to let the first flush of debris and sediment pass in the river and not compromise the river intake or the conveyance pipeline to the reservoir.

High River Flow Diversions At flows above 2000 cfs it is assumed that only 20 cfs is being diverted for keeping the irrigation system watered up while reducing the risk to the system from debris in the river and movement of gravels on the river bed.

4.3 Project Operations

The OM implements the complexity of criteria and parameters into simulations of project operations for diverting flows, meeting irrigation demands, reservoir filling, reservoir emptying, and estimating what flow remains in the Walla Walla River. A graphical illustration was developed to provide a better understanding of how the parameters change and are interrelated. Figure 4-1 presents approximately 3 years of simulating the project operations. The 3 years are centered around WY 1988. The WY of 1988 is the critical low water supply during the period of record. It presents challenges, being preceded by the previous year almost emptying the reservoir. The illustrations show both definitions of parameters and sequence of events provided in Table 4-5. Definitions are presented using alpha characters. The sequence of events is shown using numerical characters. The sequence of events also demonstrates how changing operating rules during a low water supply situation could avoid or minimize a summer/fall shortage.

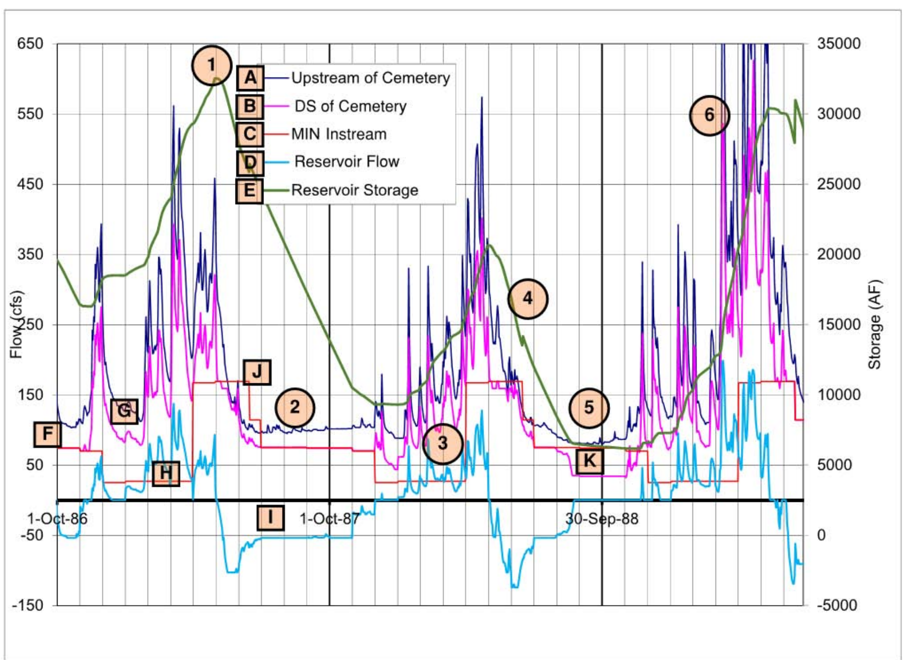


Figure 4-1. Simulation of Project Operations

Table 4-5. Definitions and Sequence of Events Illustrated in Figure 4-1

Definitions

A	Upstream of Cemetery Bridge	Flow in the Walla Walla River that is upstream of the POD before any irrigation diversion including upstream irrigators. It represents historical natural flow.
B	DS of Cemetery	Flow remaining in the Walla Walla River after the irrigation diversions both upstream of the POD and at the POD (Little Walla Walla River and reservoir filling).
C	MIN Instream	Minimum Instream represents the flow below Cemetery Bridge to meet the instream flow targets below Nursery Bridge. It includes Eastside Irrigation which is diverted at Nursery Bridge and river seepage for the reach between Cemetery Bridge and Nursery Bridge.
D	Reservoir Flow	Flow in and out of the reservoir. Flow into the reservoir is a positive value and out of the reservoir is a negative value.
E	Reservoir Storage	The total storage is shown on the secondary axis. Total storage includes the conservation pool of 6,500 AF.
F	Direct Flow	The difference between river flow and the minimum instream is water supply that can be used directly from the river to meet irrigation demands. It reduces the amount of storage flow required while still maintaining the minimum instream flow requirement.
G	Winter Irrigation	Irrigation diversions from November through April. Winter diversions decrease the amount of flow available to fill the reservoir as it is included in the allowable incremental flow reduction.
H	Reservoir Inflow	Flow available within the incremental flow reduction of river flows and after meeting the winter irrigation demands. It is only available during the reservoir filling period.
I	Reservoir Outflow	Flow released from the reservoir to replace irrigation diversions that would have reduced the river flow below the minimum instream flow targets.
J	Spring Shortage	Difference between the minimum instream flow target and the flow in the Walla Walla River downstream of the POD during the spring period. The shortage is caused by the natural flow in the river being less than the flow targets. The only way to avoid a spring shortage is to augment or supply water in the river that is in excess of natural flows which is not done. It should also be noted that spring flows are reduced by irrigation diversions that do not receive water supply from the reservoir such as upstream irrigation and East Side.
K	Summer/Fall Shortage	Difference between the minimum instream flow target and the flow in the Walla Walla River downstream of the POD during the summer/fall time. The shortage is typically caused by the reservoir being empty and unable to replace irrigation diversions. The irrigation diversions are reduced to maintain current policy for instream flows of Protected Instream flow and USFWS flow.
SEQUENCE OF EVENTS		
1	Reservoir does not fill	The winter water supply needed to fill the reservoir was low in WY 1987 and not able to fill the reservoir to capacity.
2	Reservoir Depleted	The river flows remained low thru the summer and fall in WY 1987 with limited direct flow available requiring use of the reservoir water resulting in depletion almost to the conservation pool going into December.
3	No water available for filling	The reservoir is only able to fill approximately half full due to the low winter flows.
4	Reservoir drawdown to meet spring Target Flows	With low river in the spring of WY 1988, the reservoir storage is rapidly depleted to meet the irrigation demand and keep the 150 and 125 cfs in-river for spring migration. Recognizing that the reservoir is low, operators may have reduced this demand for optimal river conditions and saved water for summer to avoid running out and hitting critical lows.

Table 4-5. Definitions and Sequence of Events Illustrated in Figure 4-1
Definitions

5	Reservoir empty	The reservoir emptied and the flow targets were not achieved in October and November. This condition could have likely been avoided by recognizing the low water supply in the spring and reducing instream flows to spread the flow over the summer.
6	Recovers in WY 1989	The water supply returns to near average and allows for filling the reservoir and recovery to near normal conditions.

4.4 Project Performance

Project performance or more specifically reservoir performance is defined in many ways. The following sections looks at different parameters to characterize the results of the simulations.

4.4.1 Firm Yield

Reservoir performance is defined by quantifying the firm yield. The firm yield of a reservoir is typically defined as the maximum yield that could have been delivered without failure during the historical drought of record. As such, it is representing the worst historical scenario. The historical drought of record is the years leading up to and following WY 1988. The small reservoir system can provide 18,400 AF which is an average of approximately 43 cfs from May 1 thru November 30 (213 days). The large reservoir system can provide 22,200 AF, which is an average of approximately 53 cfs from May 1 thru November 30.

4.4.2 Shortages

Shortages are defined as the difference between what is required at Cemetery Bridge to achieve the minimum instream flow target below Nursery Bridge and the flow in the Walla Walla River downstream of the POD during the spring time. Figure 4-2 shows the years when that a summer or fall shortage occurred and the volume of the shortage. Over the 47 years of the simulation, there were 5 years with shortages for the small reservoir and there was 1 year with shortages for the large reservoirs.. The percentage of years with shortages is approximately 10 percent and 2 percent of the time for the small and large reservoirs, respectively. The average annual volume for shortages when they occurred is 3,530 AF and 980 AF for the small and large reservoirs, respectively.

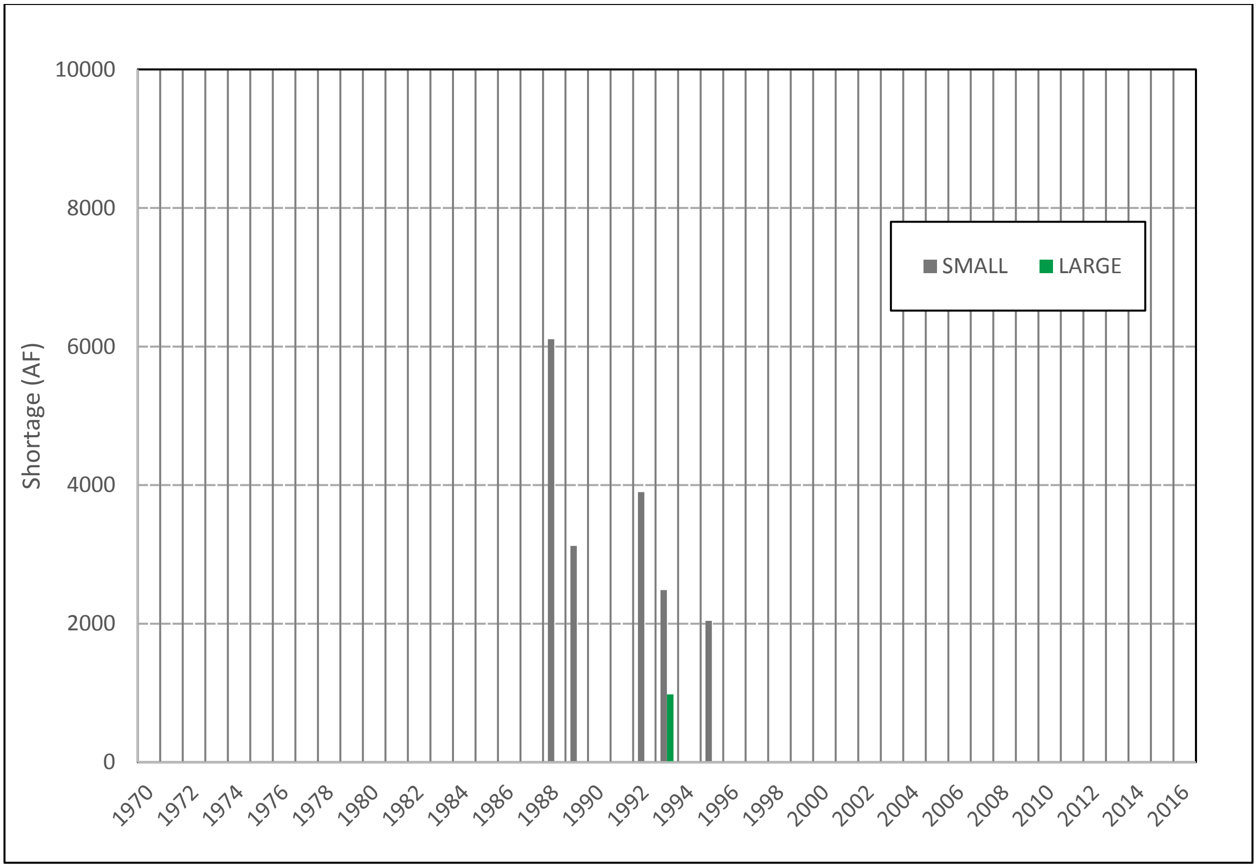


Figure 4-2. Annual Flow Shortages During the 47-Year Simulation for the Small and Large Reservoir

4.4.3 Reservoir Filling and Utilization

Many reservoirs do not fill every year and still achieve the objectives of meeting demands and not having shortages. Reservoir filling though is an indicator of whether the reservoir is sized appropriately for the water supply while meeting demands. Figure 4-3 shows the fill and empty cycle of reservoir storage for each of the years. The small and large reservoirs would fill 80 percent and 70 percent all years, respectively. During wet years, the reservoir storage is not fully utilized and most of the irrigation demand is satisfied. This indicates that during these years, the reservoir could be more utilized to meet irrigation demands and the instream flow targets could increase. Figure 4-4 shows the water supply being utilized from the Walla Walla River under the current criteria for the small reservoir. It also shows the potential water supply from the Walla Walla River that could be used to fill the reservoir if there was available storage. The average annual difference is 5,900 AF. The Project has the potential to provide greater benefits if the instream flow targets changed for the hydrologic conditions. During wet years, the instream flow targets would increase and during dry years, the instream flow targets would need to lower. The risk of not having carry over storage when needed though increases. Applying more sophisticated operating rules and project experience would develop the relationship of reservoir storage levels, direct flow available, and flow targets to better utilize the storage.

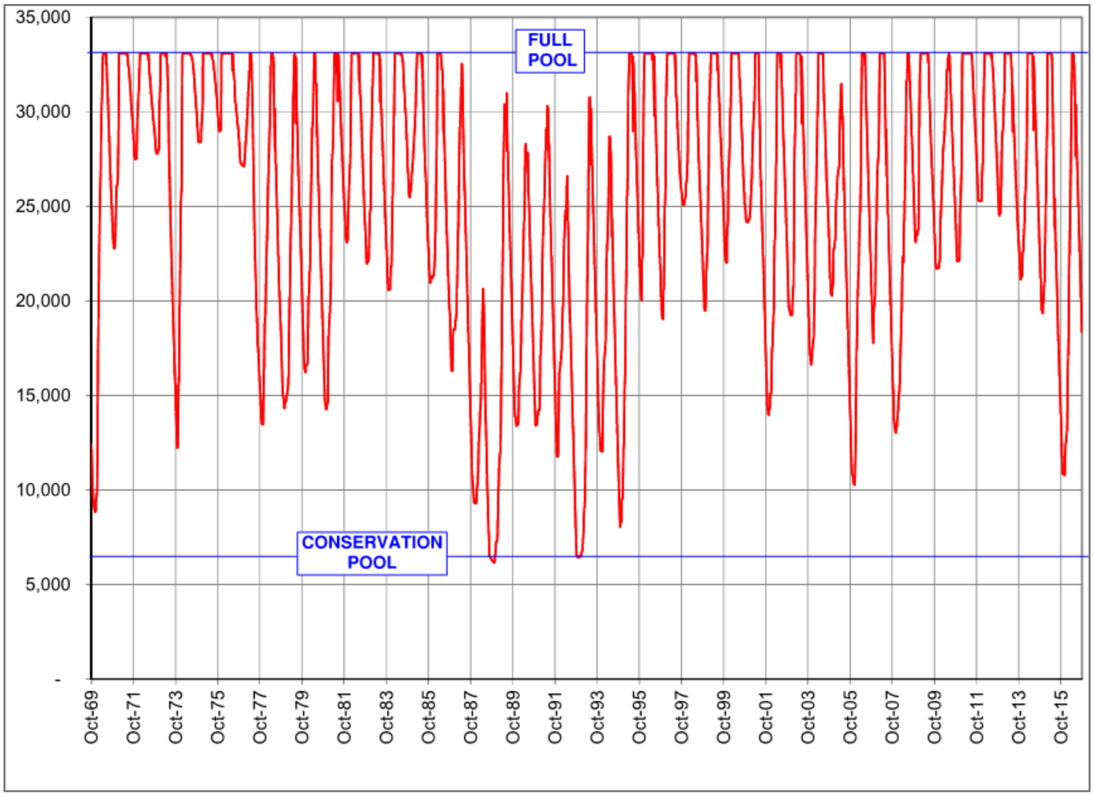


Figure 4-3. Fill and Empty Cycle of the Active Storage for the Small During the 47-Year Simulation

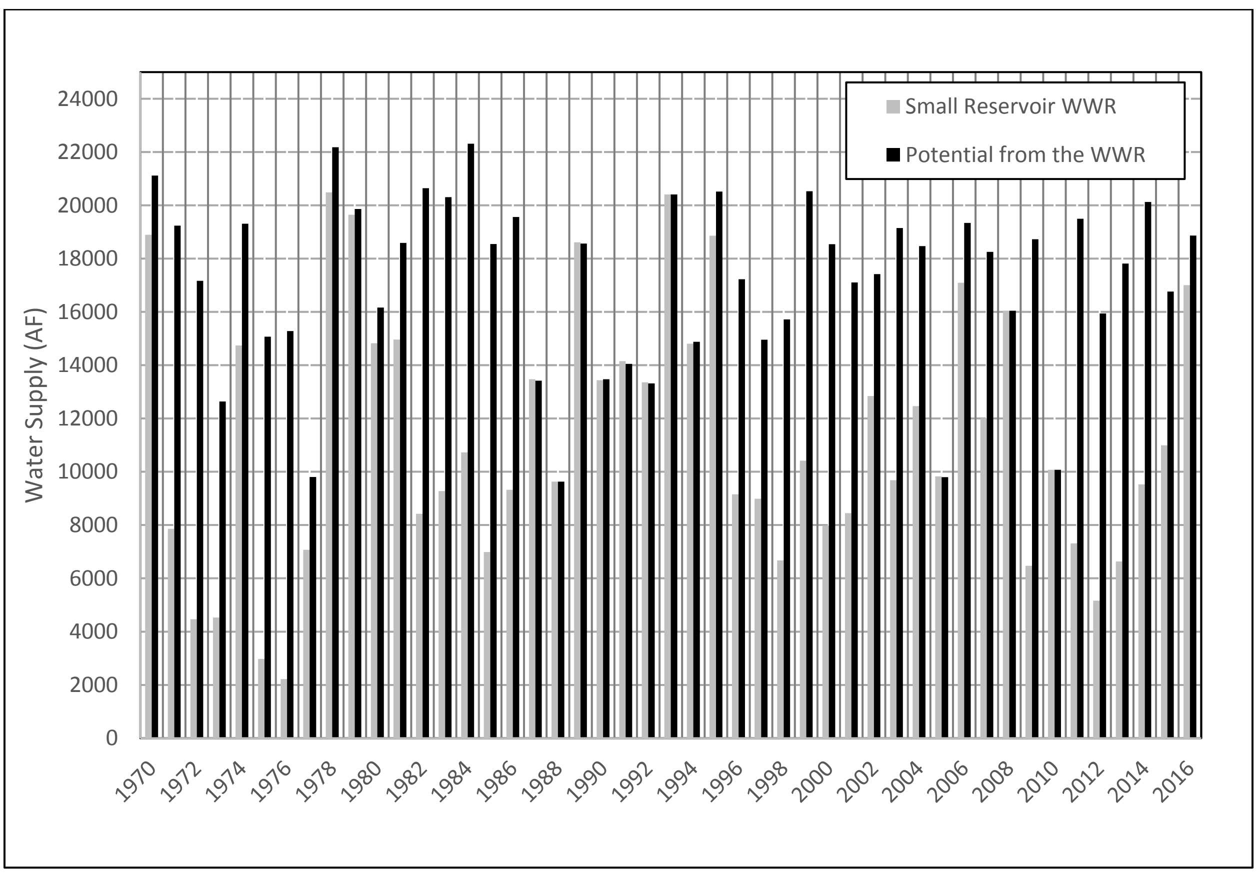


Figure 4-4. Water Supply From the Walla Walla River to Reservoir Storage for the Small Reservoir During the 47-Year Simulation

4.4.4 Pumping Requirements

The two reservoirs will operate at different water levels while meeting the irrigation demands. The smaller reservoir will be at a lower water level more frequently requiring a booster pump to meet irrigation demands at the FROG. Figure 4-5 shows the days of water pumped to the FROG to meet irrigation demands. There is approximately 23 percent and 11 percent of the years that require pumping with an average volume of 940 AF and 1500 AF for the small and large reservoirs, respectively. An annual cost was estimated by assuming a cost of $15 per kilowatt for peak power and $0.10 per kilowatt hour for energy. The results are an average pumping cost for the fraction of years it occurred of $3,900 and $5,400 for the small and large reservoir, respectively.

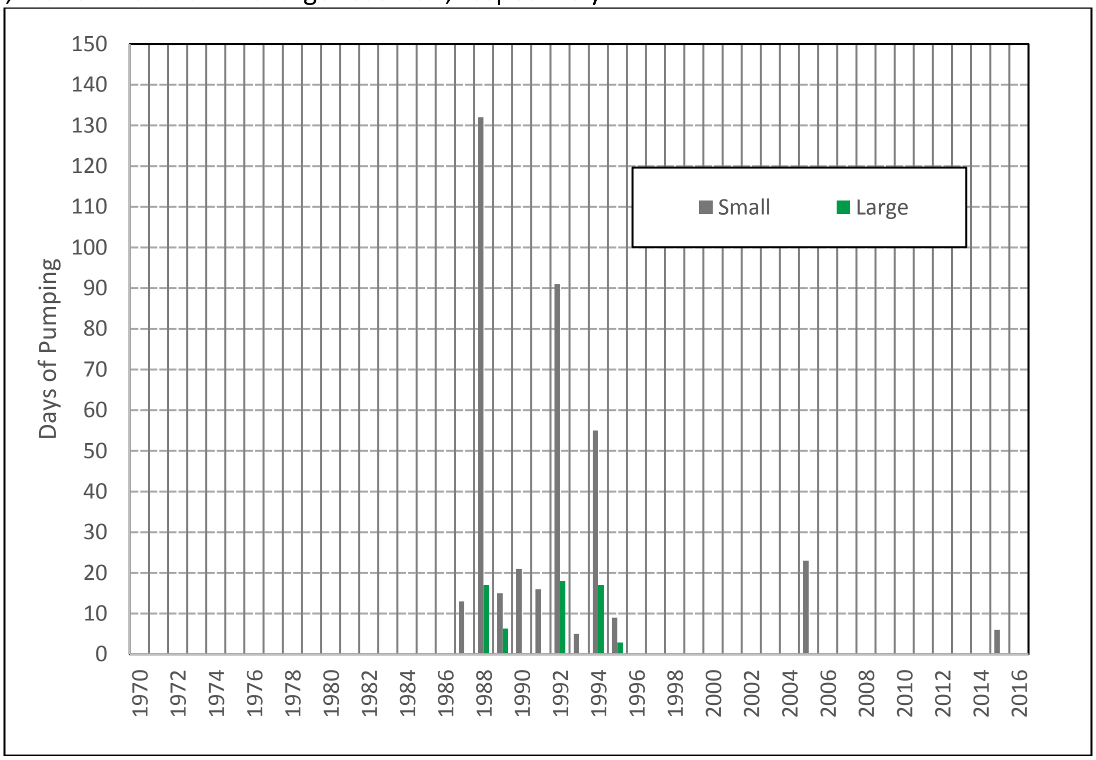


Figure 4-5. Annual Pump Requirements for the Small and Large Reservoir During the 47-Year Simulation

4.4.5 Performance Summary

A summary of performance parameters from the preceding sections is presented in Table 4-6 to compare the small and large reservoir alternatives.

Table 4-6. Summary of Project Performance for the Small and Large Reservoir

Parameter	Small Reservoir	Large Reservoir
Firm Yield	18,400 AF Average of 43 cfs instream river flow	22,200 AF Average of 52 cfs instream river flow
Summer/Fall Shortages	5 years out of 47 10% of years Average annual 3,530 AF shortage per occurrence	1 year out of 47 2% of years Average annual 980 AF shortage per occurrence
Reservoir Filling	80% of years filled 13,900 AF of average annual yield [a] Potential increase of 5,900 AF [b]	70% of years filled 14,100 AF of average annual yield [a]

Table 4-6. Summary of Project Performance for the Small and Large Reservoir

Parameter	Small Reservoir	Large Reservoir
Pumping Requirements	11 years out of 47	5 years out of 47
	23% of years	11% of years
	Average annual 941 AF pumping per occurrence	Average annual 1500 AF pumping per occurrence
	Average annual $5,400 pumping cost per occurrence	Average annual $3,900 pumping cost per occurrence

[a] Does not include the 3 percent volume assumed for operational inefficiencies.

[b] Potential increase is from managing storage to replace additional irrigation diversions during wet years while limiting to minimum flow targets during dry years

Cost Estimate

5.1 Capital Cost

A Class IV cost estimate as defined by AACE International was developed for the proposed project. The cost estimates presented in this section include capital costs for the recommended dam, reservoir, conveyance pipelines and pump station facilities described in this report and depicted on the associated drawings. Costs for power transmission from the source of power to the pump station site are not included.

The purpose of this conceptual design phase construction cost estimate (estimate) is to aid strategic planning, project screening, alternative scheme analysis, confirmation of economic and or technical feasibility, and preliminary budgeting for proposed projects. This estimate is prepared based on limited field and design-specific information where the conceptual engineering is less than 15 percent complete. Examples of estimating methods used would be equipment and or system process factors, scale-up factors, and parametric techniques. The expected accuracy ranges for this class of estimate are -15 percent to -30 percent on the low range side and +20 percent to +50 percent on the high range side.

The costs presented include general conditions and contractor overhead and profit. Also included are a 20 percent contingency for the dam and reservoir and 25 percent for the pump station and pipeline facilities. The contingency allowance is intended to account for changes in the project scope and items that have not been defined at the conceptual level of project design. Cost are presented in third quarter 2017 dollars and no escalation has been provided.

The overall estimated capital cost for the project is summarized in Table 5-1. More detailed information regarding the cost for the various facilities is provided in Appendix D.

Table 5-1. Summary of Estimated Capital Cost for Pine Creek Reservoir Project

Facility	Estimated Capital Cost ($1000s)
RCC Dam (small)	201,389
RCC Dam (large)	240,259
78-inch Main Conveyance Pipeline	64,749
Irrigation Distribution Pipeline	8,465
Pump Station	2,200
Project Total (small dam)	**276,803**
Project Total (large dam)	**315,673**

5.1.1 Dam and Reservoir

Material quantity and cost estimates were performed for two RCC Gravity dam options, (1) large dam with active reservoir capacity of 39,300 AF and (2) small dam with active reservoir capacity of 26,600 AF. The same dam alignment was assumed for both alternatives.

The Inroads civil engineering module in the Bentley Microstation CAD software was used to create a base map of the available topographic information. Using this base map and the available subsurface information, assumptions regarding foundation excavation was made and modeled in 3D with the Inroads software. Following excavation, the dam structures were modeled, resulting in the respective 3D models of the two dam alternatives. These 3D models were then utilized to extract relatively accurate estimates of (1) reservoir volume, (2) reservoir area, (3) excavation volume, and (4) dam volumes.

The approaches for estimating quantities and unit prices for the main dam elements used in the construction cost estimates are detailed below:

Quantities

1. *RCC Volume*: For the RCC dams, the two main cost components are the RCC (including the material, placement, compaction, formwork, and drain installation) and the foundation excavation. An RCC volume of 1,203,200 cubic yards (y^3) and excavation quantity of 601,200 y^3 (334,600 y^3 soil and 266,600 y^3 rock) were computed for the small dam, and an RCC volume of 1,477,200 y^3 and excavation quantity of 657,600 y^3 (363,100 y^3 soil and 294,500 y^3 rock) were computed for the larger dam.

3. *Foundation Grouting Quantities*: It was assumed that grouting would be performed prior to constructing the dam. Note, however, that if grouting is performed from within the RCC dam gallery, it will be more expensive than grouting performed in the open. The schedule advantages associated with taking grouting off the critical path is likely to offset the disadvantages, including extra cost, of grouting from the gallery. The following assumptions were made in estimating the quantities associated with the foundation grouting:

   a. Foundation grouting will include a two-row grout curtain and two rows of blanket grout holes, with a blanket grout row on each side of the curtain.

   b. Average spacing of the grout curtain holes will be 7.5 feet for total of 748 holes—assume final pattern hole spacing of 10 feet with some areas of tertiary grouting with final hole spacing of 5 feet. Assume that average depth of holes in center 50 percent of curtain will be 200 feet, and average depth of the holes at the abutments will be 100 feet. Note that final hole depth and spacing will depend on the geologic conditions and estimates of these parameters are typically refined after a test grouting program is performed on site.

   c. Spacing of blanket grout holes of 7.5 feet for total of 747 blanket grout holes. The assumed depth of the holes is 25 feet.

   d. Grout take is 1 sack (94 pounds) per 1 lineal foot, on average. Microsilica content is 10 percent of cement.

   e. Perform upstage grouting with average grout stage length of 15 feet. Assume two extra hook-ups per grout curtain hole. Assume one hook-up for each of the blanket grout holes.

   f. Water pressure testing—assume 600 hours of testing.

   g. Verification boring every 100 feet along curtain for total of 28 borings. Assume average length of verification boring = 150 feet

Unit Prices

Since the unit prices for RCC and rockfill are the two factors that largely control the construction costs, most effort was spent to develop unit prices for these elements.

1. *RCC Construction Unit Price*: A unit price for RCC was developed making assumptions on the unit cost for cement, flyash and aggregate. Prices of $134, $65, and $10.88 per ton were assumed for cement, flyash, and aggregate, respectively. Other items included plants and delivery system, forming and facing systems, galleries, shafts and audits and spreading, compaction and curing.

Accounting for all these components, a direct RCC cost of about $73 per cubic yard was estimated. This price does not include any overhead and profits.

5.1.2 Conveyance and Distribution Pipelines

Pipeline lengths were estimated using desktop methods, available aerial photography, and CAD software such as MicroStation and Google Earth. Pipeline unit costs for steel and HDPE pipelines include pipe fabrication and delivery to the job site, open cut excavation, placing the pipeline, welding of joints, and granular backfill in the pipe zone. In open farm land and undeveloped areas, backfill above the pipe zone is native material compacted to 85 percent of maximum density. In urban locations, unit costs include pavement removal, an allowance for utility relocations, granular road base compacted to 90 percent of maximum density, and asphalt surfacing. Unless otherwise indicated, pipelines are assumed to be installed by open cut methods with a nominal 3-feet of cover. Rock excavation and groundwater control are not anticipated or included in the pipeline costs. A robust geotechnical investigation during design may reveal locations where rock and groundwater removal are required. Pipe wall thickness or pressure class assumptions are provided in the estimates. All cost estimates are shown in 2017 dollars and are based on comparisons with other projects and data available in the RS Means database.

5.2 Annual Operations and Maintenance Costs

Typical O&M costs, excluding the cost of power, were established as a percent of the capital cost for each facility as summarized in Table 5-2. These costs are expected to account for general upkeep, repair and replacement of minor items, and normal efforts required to inspect and monitor the facility as well as keep it in good condition and functional (including such tasks as periodic painting and cleaning, or lubrication). Factors were developed from past project experience and are expected to be conservatively high.

Table 5-2. Operations and Maintenance Cost Factors by Facility

Item	Annual O&M Cost Factor (Percent of Initial Capital Cost)
Roller Compacted Concrete Dam	0.1
Conveyance Pipelines	1.0
Pump Station	0.5

Annual power required for pumping would be highly variable depending on water-year type. In a wet to average year, no pumping would be required and the power cost would be zero. In a dry year, the operations model suggests that pumping may be needed up to 130 days per year. For this estimate of average annual O&M costs, 10 days of pumping was assumed at $0.1/kWh, 80 percent pumping efficiency, and 5 percent administrative power for non-pumping equipment. Table 5-3 provides a summary of the total estimated annual O&M cost.

Table 5-3. Estimated Annual Operations and Maintenance Cost Summary

Item	Annual O&M Cost ($1000s)
General O&M	
RCC Dam (small)	201
RCC Dam (large)	240
78-inch Main Conveyance Pipeline	647
Irrigation Distribution Pipeline	85
Pump Station	11
Power	3
Project Total (small dam)	**947**
Project Total (large dam)	**986**

SECTION 6

Recommendations for Next Steps

6.1 Project Implementation

The Pine Creek Reservoir alternative and the Walla Walla Pump Exchange (or Pump Back) alternative have been under consideration for many years as potential means of addressing water supply and fish passage/habitat challenges in the basin. The next step toward project implementation is for decision-makers and stakeholders within the Walla Walla River Basin to select one of these alternatives as the "preferred" project concept, and then initiate preliminary designs and environmental studies for the preferred concept.

Due to the considerable complexity of these alternatives and the diverse interests of basin stakeholders, WWBWC may want to consider a decision support process that would consist of a rigorous, defensible, and impartial side-by-side comparison of the two alternatives using evaluation criteria selected by, and important to, the basin stakeholders. The two alternatives should be compared and evaluated on a "level playing field" that identifies and prioritizes stakeholder values using a transparent and reproducible process. Key components of this process would include the following:

- Verifying that both alternatives have had adequate detail developed on the key elements to be comparable
- Conducting a preliminary screening of cultural and environmental impacts and potential impact mitigation requirements
- Developing comparable cost information for both alternatives including the initial investment, operations, maintenance, and replacement costs
- Engaging stakeholders in establishing cost and non-cost evaluation criteria and a decision science process for weighting and scoring the alternatives against the criteria. Evaluation criteria would typically include five categories of considerations: 1) constructability considerations, 2) environmental, regulatory, and permitting considerations, 3) operations and maintenance considerations, 4) community goals and stakeholder acceptance, and 5) cost
- Arriving at consensus on a preferred alternative

Following such a process, more detailed design and environmental compliance steps could be initiated. Section 6.2 identifies several near-term action items that WWBWC should consider to feed into this process and determine additional key project details, refine and advance estimates of cost, establish a more definitive timeline for implementation, and ensure proper planning for critical path activities.

6.2 Recommended Near-Term Action Items

Key design considerations for the Pine Creek Project, which are vital to technical and economic feasibility, should be advanced to ensure that constructability and costs considerations are appropriately represented and comparable to the Pump Back Alternative. Additionally, key elements of the Pump Back Alternative should be examined to ensure that level playing field comparison with the Pine Creek project is also feasible.

6.2.1 Pine Creek Dam

6.2.1.1 Subsurface Investigation for Pine Creek Dam

To confirm feasibility and cost of a dam at the proposed dam alignment, additional site-specific subsurface information is necessary. It is recommended that a geotechnical exploration be performed that comprise the following four minimum elements:

1. Six borings along the centerline of the dam. Parameters of interest would include the top of bedrock, strength of the rock, the degree and orientation of jointing and fracturing, the presence of other rock types besides basalt, and the permeability of the rock mass. Most boreholes will be vertical but some may be inclined. Proposed in situ testing will include the following:
    - Water pressure (packer) tests to estimate the permeability of the rock mass.
    - Optical and acoustical televiewer logging in the holes to record continuous color images of the in situ rock. The purpose of this logging will be to determine the nature of the rock in zones of potential rock core loss and to evaluate the nature and orientation of joints, shears, bedding and other discontinuities in the rock.
2. Four to six borings at an identified quarry site for sourcing of RCC aggregate and rockfill.
3. A test quarry blasted to dimensions specified by the Engineer. The test quarry will only be performed at the proposed location if the rock cores recovered from the geotechnical borings confirm the suitability of the site. The purpose of the test quarry will be (1) to investigate the suitability of the rock as RCC aggregate, which is a major issue in determining the feasibility of constructing an RCC dam, and (2) to investigate the nature of the rockfill that will be produced as quarry run. Sound rock recovered from the quarry will be transported to the crusher where it will be processed. The processed material will be stockpiled and used for laboratory testing including for RCC trial mixtures.
4. Identification of potential clay borrow sources within 10 miles of the site. Excavation of estimated 15 to 20 test pits to evaluate quantity and suitability of clay for use as dam core.

Since a high concrete gravity dam (such as the RCC dam) requires a competent foundation of hard rock with low degree of weathering, the discovery of relatively poor rock conditions during subsurface investigations could promote selection of a earthfill or rockfill embankment dams.

6.2.1.2 Type of Dam

Following the subsurface investigation, it is recommended that a more rigorous comparisons and optimizations evaluation be performed in a next phase to select the most appropriate and cost-effective dam type for the site. Besides the two dam types (earthfill embankment and RCC gravity dam) originally identified by the USACE, other dam types such as earth core and a concrete face rockfill dams, should also be considered.

6.2.2 Updates to Pump Back Facilities

CH2M recommends a brief review of the Pump Back project to identify and resolve discrepancies between the two concepts that could hinder head-to-head comparisons. If key design or operational criteria for the Pump Back alternative need to be revisited or adjusted, it would be important to do so prior to the decision-science evaluation. To the extent possible, both projects should include similar and comparable assumptions, such as current construction costs (2017 dollars), financing assumptions, power costs, equipment replacement intervals, project life expectancy, and water delivery rates and volumes. This review and update should be performed by WWBWC's decision-science consultant with a goal of ensuring comparable project assumptions.

6.2.3 Determine Oregon State Water Commission Needs

This study assumes a 30 percent water withdrawal rate from the Walla Walla River. The proposed guidelines by the State of Oregon have several recommended analyses to justify an increased river diversion rate greater than 15 percent for water storage projects. WWBWC should consider submitting a water rights application to the state and conducting a workshop with the State to present the process, findings, and conclusions of this study. The workshop would facilitate discussions on additional hydrologic, geomorphic, and biological investigations that may be required to justify the 30 percent withdrawal rate. There may be operational criteria that have not been considered or assumptions that are not consistent with State guidelines. In addition, our experience has been that early engagement promotes communication, cooperation and a positive working relationship.

6.2.4 Initial Cultural and Environmental Resource Screening

CH2M recommends WWBWC conduct an initial screening of potential resource impacts and mitigation measures for each alternative. The intent would be to provide a basis for decision support and selection of a preferred alternative, and to help inform subsequent scoping of field work and preparation of National Environmental Policy Act documentation.

6.2.5 Land Ownership Maps

Access agreements for field investigations and early discussions on right-of-way acquisition and permitting will require more information on current land ownership. CH2M recommends an initial desktop study to collect existing information on land ownership records. The land ownership information will be plotted on existing aerial photography.

References

Baltz, D., M.B. Vondracek, L.R. Brown, and P.B. Moyle. 1991. "Seasonal Changes in Microhabitat Selection by Rainbow Trout in a Small Stream." Transactions of the American Fisheries Society. Volume 120.

Bass, 1991

Bjornn, T.C. 1971. "Trout and Salmon Movements in Two Idaho Streams as Related to Temperature, Food, Streamflow, Cover, and Population Density." *Transactions of the American Fisheries Society. Volume 100.*

Brown, R.S. and W.C. Mackay. 1995. "Fall and Winter Movements of and Habitat Use by Cutthroat Trout in the Ram River, Alberta." *Transactions of the American Fisheries Society*. Volume 124.

Campbell, R.F. and J.H. Neuner. 1985. "Seasonal and Diurnal Shifts in Habitat Utilized by Resident Rainbow Trout in Western Washington Cascade Mountain Streams," in F.W. Olson, R.G. White, and R.H. Hamre, editors. Proceedings of the Symposium on Small Hydropower and Fisheries. American Fisheries Society, Bethesda, Maryland.

Castro, J. and P. L. Jackson. 2001. *Bankfull Discharge Recurrence Intervals and Regional Hydraulic Geometry Relationships: Patterns in the Pacific Northwest,* USA. Jour. Wat. Res. Assoc. Volume 37(5).

CH2M. May 1983. Preliminary Design Report for French Canyon Dam and Regulating Reservoir. Yakima-Tieton Irrigation District. Yakima, WA. Rehabilitation and Betterment Project.

CH2M. September 2013. Yakima-Tieton Irrigation District Main Canal Rehabilitation and Cowiche Creek Water Exchange. Alternatives Study. Yakima-Tieton Irrigation District. Yakima, WA.

Clarke, Sharon E.; Bryce, Sandra A., eds. 1997. Hierarchical subdivisions of the Columbia Plateau and Blue Mountains ecoregions, Oregon and Washington. Gen. Tech. Rep. PNW-GTR-395. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 114 p.

Don Chapman Consultants. 1989. *Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead Trout in the Wenatchee River, Washington.* Prepared for the Chelan County Public Utility District, Wenatchee, Washington. June.

Fell, Robin, MacGregor, Patrick, Stapledon, David, Bell, Graeme, and Mark Foster. 2015. Geotechnical Engineering of Dams. 2nd Edition. CRC Press.

Frankel, A.D., Peterson, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S. 2002. Documentation for the 2002 Update of the National Seismic Hazard Maps. USGS. Open-File Report 02-420.

GeoEngineers, 2012. *Alternatives Analysis and Conceptual Design Milton-Freewater Levee and Habitat Walla Walla River Milton-Freewater, Oregon.* Prepared for Walla Walla Basin Watershed Council. February 23.

Geomatrix Consultants. 1995. Seismic Design Mapping, State of Oregon, Final Report. Prepared for Oregon Department of Transportation.

Goldfinger, C. 2003. "Deep-water turbidites as Holocene earthquake proxies: the Cascadia subduction zone and Northern San Andreas Fault systems." Annals of Geophysics, Vol. 46, No. 5, October 2003.

Hannum, Michelle. Letter to Scott Tomren RE: Bear Canyon Repeater, Location # 348368, Yakima County, Washington Utility Line Survey. Plateau Archaeological Investigations, LLC 2008.

Heggenes, J.O., M.W. Krog, O.R. Lindas, J.G. Dokk, and T. Bremmnes. 1993. "Homeostatic Behavioral Responses in a Changing Environment: Brown Trout (Salmo trutta) Become Nocturnal During Winter." *Journal of Animal Ecology*. Volume 62.

Hyndman, R.D. and Wang, K. 1995. "The rupture zone of Cascadia great earthquakes from current deformation and the thermal regime," J. Geophys. Res., v. 100, p. 22,133-22,154.

ICOLD. 2004. Concrete Face-Rockfill Dams – Concepts for Design and Construction, International Commission on Large Dams, Committee on Materials for Fill Dams, November, 2004.

ICOLD, Concrete Face Rockfill Dams. Concepts for design and construction, International Commission on Large Dams, Bulletin 141 (2010).

Kelly, Katherine M. WDFW Tieton River Relic Diversion Removal. WDFW Archaeological Report No. 2015-30. 2015

Knowles, S.M. and Sumioka, S.S., 2001, The National Flood-Frequency Program—Methods for Estimating Flood Magnitude and Frequency in Washington, 2001: U.S. Geological Survey Fact Sheet FS-016-01, 4 p.

LaVasser, J. 2004. Personal Communication. March 3, 2004.

Lasmanis, R. 1991. "The Geology of Washington: Rocks and Minerals." Rocks and Minerals. Vol. 66, No. 4. pp. 262-277.

Lidke, D.J., compiler, 2002, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed on 09/06/2006

Lidke, D.J., compiler, 2003, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed on 09/06/2006

Lidke, D.J., and Bucknam, R.C., compilers, 2002, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed on 09/06/2006

Ludwin, R.S., Dennis, R., Carver, D., McMillan, A.D., Losey, R., Clague, J., Jonientz-Trisler, C., Bowechop, J., Wray, J., and James, K. 2005. "Dating the 1700 Cascadia Earthquake: Great Coastal Earthquakes in Native Stories." Seismological Research Letters, Vol. 76 No. 2, March/April 2005, Seismological Society of America, pp 140-148.

McClure, R. Jr. Washington State Department of Archaeology and Historic Preservation Archaeological Site for 45YA123. 1979

McCrory, P.A., Blair, J.L., Oppenheimer, D.H., and Walter, S.R. 2004. "Depth to the Juan de Fuca Slab Beneath the Cascadia Subduction Margin—A 3-D Model for Sorting Earthquakes." USGS Data Series 91. Available online at: http://pubs.usgs.gov/ds/91

Norman, David K., Dunn, Andrew B., and Catherine M Kenner. 2001. Reconnaissance Investigation of Sand, Gravel, and Quarried Bedrock Resources in the Mount St. Helens 1:100,000 Quadrangle, Washington. Information Circular 95, October 2001, Washington Division of Geology and Earth Resources.

Oregon State Water Commission (OSWC). 2014. "A Proposed Percent of Flow, an Approach for Water Storage Projects in Oregon." Draft Report.

Patten, S. 2014. Walla Walla River Bed Stability and Flow Monitoring, Final Report for OWEB grant #211-6049. Walla Walla Basin Watershed Council, Feb..

Personius, S.F., and Lidke, D.J., compilers, 2003, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults, accessed on 09/06/2006

Priority Habitat and Species GIS data layer request. April 4, 2016.

Reidel, S.P. and Campbell, N.P. 1989. “Structure of the Yakima Fold Belt, Central Washington.” Geologic Guidebook for Washington and Adjacent Area. Joseph, N.L. et al. (eds.). Washington Division of Geology and Earth Resources. Information Circular 86.

Riker, Richard E., Esterhuizen, Jacob, Deere, Don, and Gabriel Fernandez-Delgado. 2016. “Designing a Hybrid Dam on a Geologic with Highly Variable Engineering Properties.” U.S. Society of Dam Conference, Denver. April.

Robison, E. 2007. *Calculating Channel Maintenance/Elevated Instream Flows when Evaluating Water Right Applications for Out of Stream and Storage WaterRights.* Oregon Department of Fish and Wildlife. Guidance Document. September.

Satake, K., Shimazaki, K., Tsuji, Y., and Ueda, K. 1996. “Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January, 1700.“ Nature 379:246-49.

Schuster, J.E. and Moses, L. 2002. Geologic Map and Geology of Washington. Washington State Department of Natural Resources.

Sierra, J. M., “Concrete Face Dam Foundations”, De Mello Volume, Editor, Edgard Bluchter, Sao Paulo, 1989

Stilson, Lee. Washington State Department of Archaeology and Historic Preservation Archaeological Site for 45YA1283. 2010

Sumioka, S.S., Kresch, D.L., and Kasnick, K.D., 1998, Magnitude and Frequency of Floods in Washington: U.S. Geological Survey Water-Resources Investigations Report 97-4277, 91 p.

Swaisgood, J. R., "Estimating Deformation of Embankment Dams Caused by Earthquakes", Presented at Association of Dam Safety Officials (ASDSO) Western Regional Conference, Red Lodge, Montana, May, 1995.

U.S. Army Corps of Engineers (USACE). 2010. Walla Walla River Basin Feasibility Study, App B -3 Draft. Jan.

USCOLD. 1999. Guidelines for Selecting Seismic Parameters for Dam Projects, United States Committee on Large Dams.

U.S. Fish and Wildlife Service (USFWS). 2016. National Wetlands Inventory. Online Mapper. http://www.fws.gov/wetlands/data/mapper.HTML. Accessed May 15, 2016.

U.S. Fish and Wildlife Service (USFWS). 2002. Chapter 11, Umatilla- Walla Walla Recovery Unit, Oregon and Washington. 153 p. In: U.S. Fish and Wildlife Service. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon.

U.S. Geological Survey (USGS). 2016. National Hydrography Dataset. http://nhd.usgs.gov/. Accessed May 10, 2016.

USGS. 2006. Quaternary Fault and Fold Database. Website: http://geohazards.cr.usgs.gov/qfaults/. United States Geological Survey. Accessed August 28, 2006.

USGS. 2006b. Seismic Hazards Mapping Project. Website: http://eqhazmaps.usgs.gov/. United States Geological Survey. Accessed May 3, 2004.

Washington Department of Fish and Wildlife (WDFW). 2008. Priority Habitat and Species List. Updated April 2014. Olympia, Washington. 177 pp.

Washington State Department of Ecology. 1993. Dam Safety Guidelines – Part IV: Dam Design and Construction. Water Resources Program. July 1993.

Washington Natural Heritage Program (WNHP) Rare Plants and High Quality Ecosystems Data, August 2015. Available at: https://test-fortress.wa.gov/dnr/adminsaqa/dataweb/dmmatrix.html. Accessed April 2016.

Washington Department of Ecology. 2002. *Walla Walla River Fish Habitat Analysis Using the Instream Flow Incremental Methodology.* As prepared by WDOE and the Washington State Department of Fish and Wildlife. December. Technical Report 02-11-009.

Wilcock, P. R., S. T. Kenworthy and J. C. Crowe, 2001, "Experimental Study of The Transport of Mixed Sand and Gravel," *Water Resources Research.* Volume 37(12).

Wolman, M.G. 1954. "A Method of Sampling Coarse River-bed Material." *Transactions of the American Geophysical Union.* Volume 35.

Wong, I., Silva, W., Bott, J., Wright, D., Thomas, P., Gregor, N., Li, S., Mabey, M., Sojourner, A., and Wang, Y. 2000. Earthquake Scenario and Probabilistic Ground Shaking Maps for the Portland, Oregon, Metropolitan Area. Oregon Department of Geology and Mineral Industries Interpretive Map Series IMS-16.

Yeats, R.S., Sieh, K., and Allen, C.R. 1997. The Geology of Earthquakes. Oxford University Press, New York. 568 p.

Appendix A
Concept Drawings

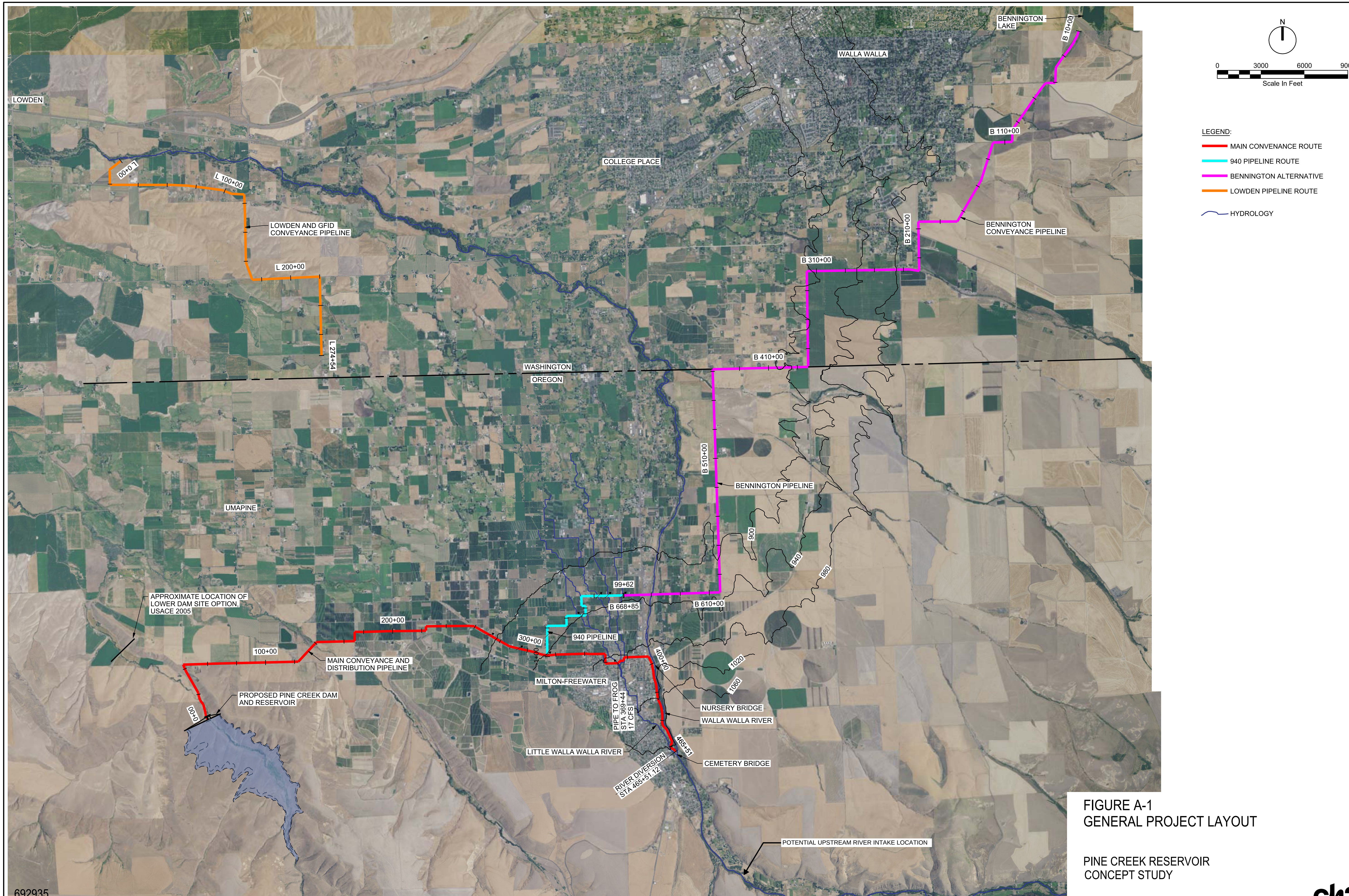


FIGURE A-1
GENERAL PROJECT LAYOUT

PINE CREEK RESERVOIR
CONCEPT STUDY

ch2m:

FILENAME: PC-FigA-1_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 4:14:46 PM

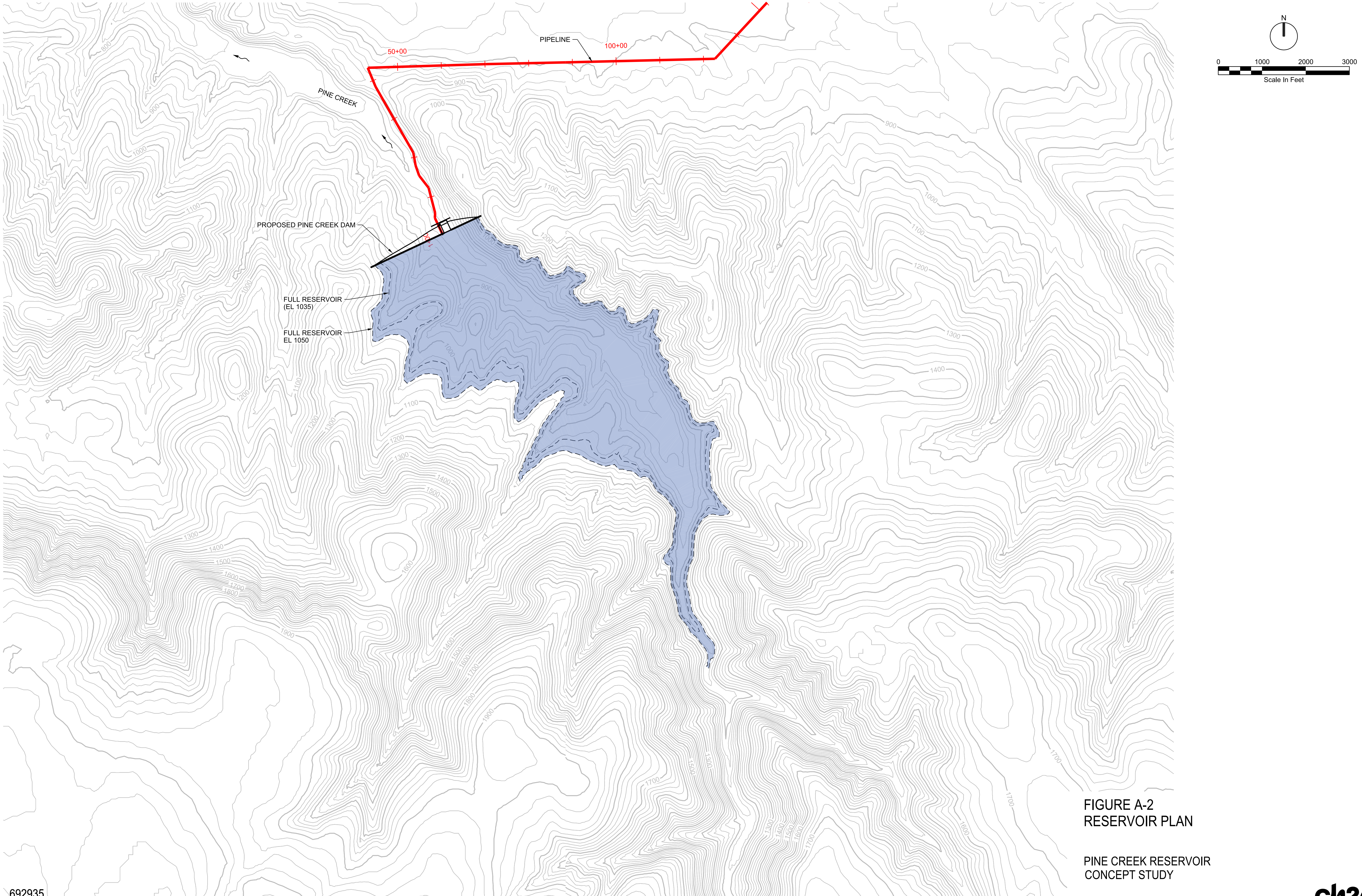
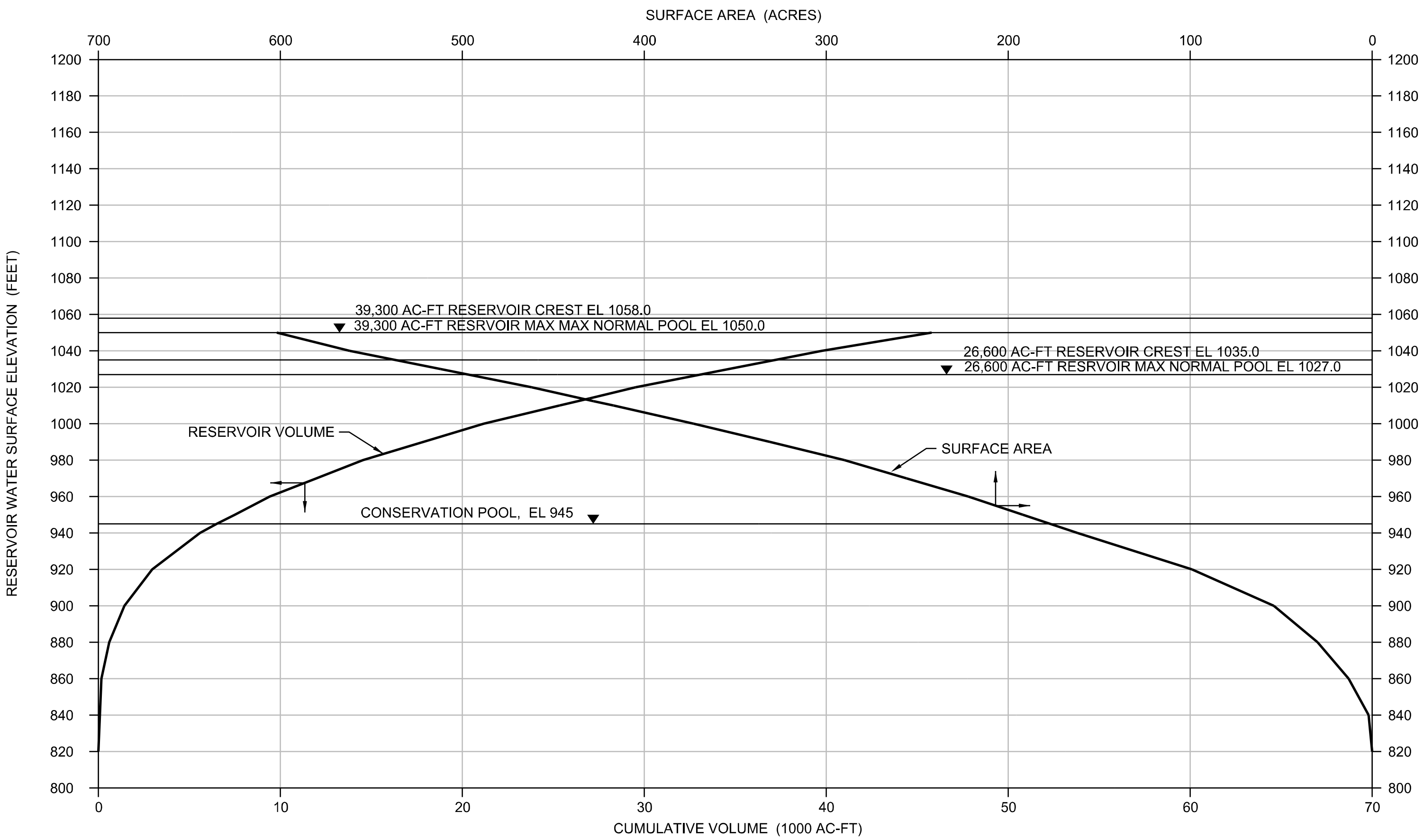


FIGURE A-2
RESERVOIR PLAN

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

ch2m



STAGE ELEVATION (FEET)	CUMULATIVE VOLUME (ACRE-FEET)	SURFACE AREA (ACRES)
820	0	0
840	16	2
860	162	13
880	589	30
900	1,423	54
920	2,953	99
940	5,571	162
950	7,494	192
960	9,417	222
970	11,979	256
980	14,542	290
990	17,856	331
1000	21,170	373
1010	25,344	417
1020	29,517	462
1030	34,640	512
1040	39,763	562
1050	45,783	602
1060	51,803	642
1080	65,494	727
1100	80,856	809

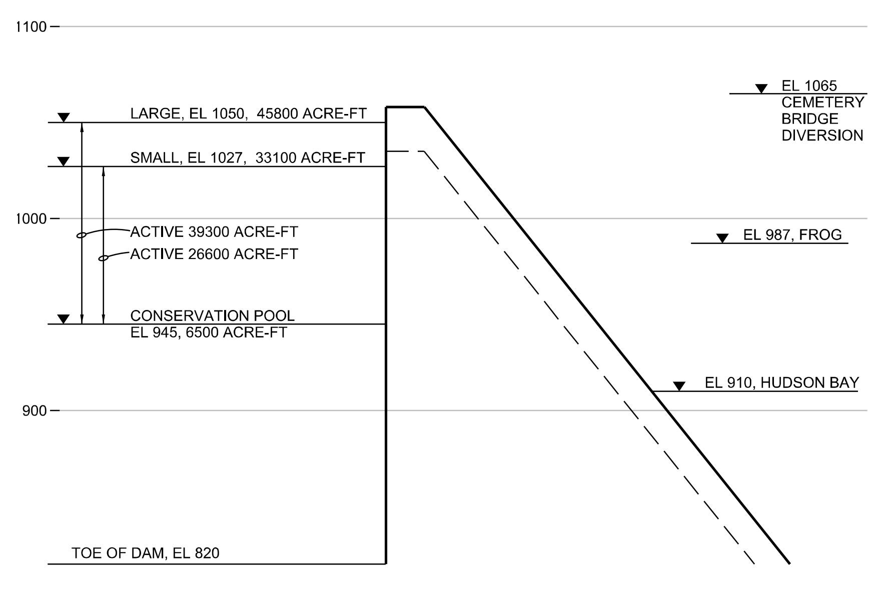


FIGURE A-3
DAM AND RESERVOIR
CAPACITY DATA

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

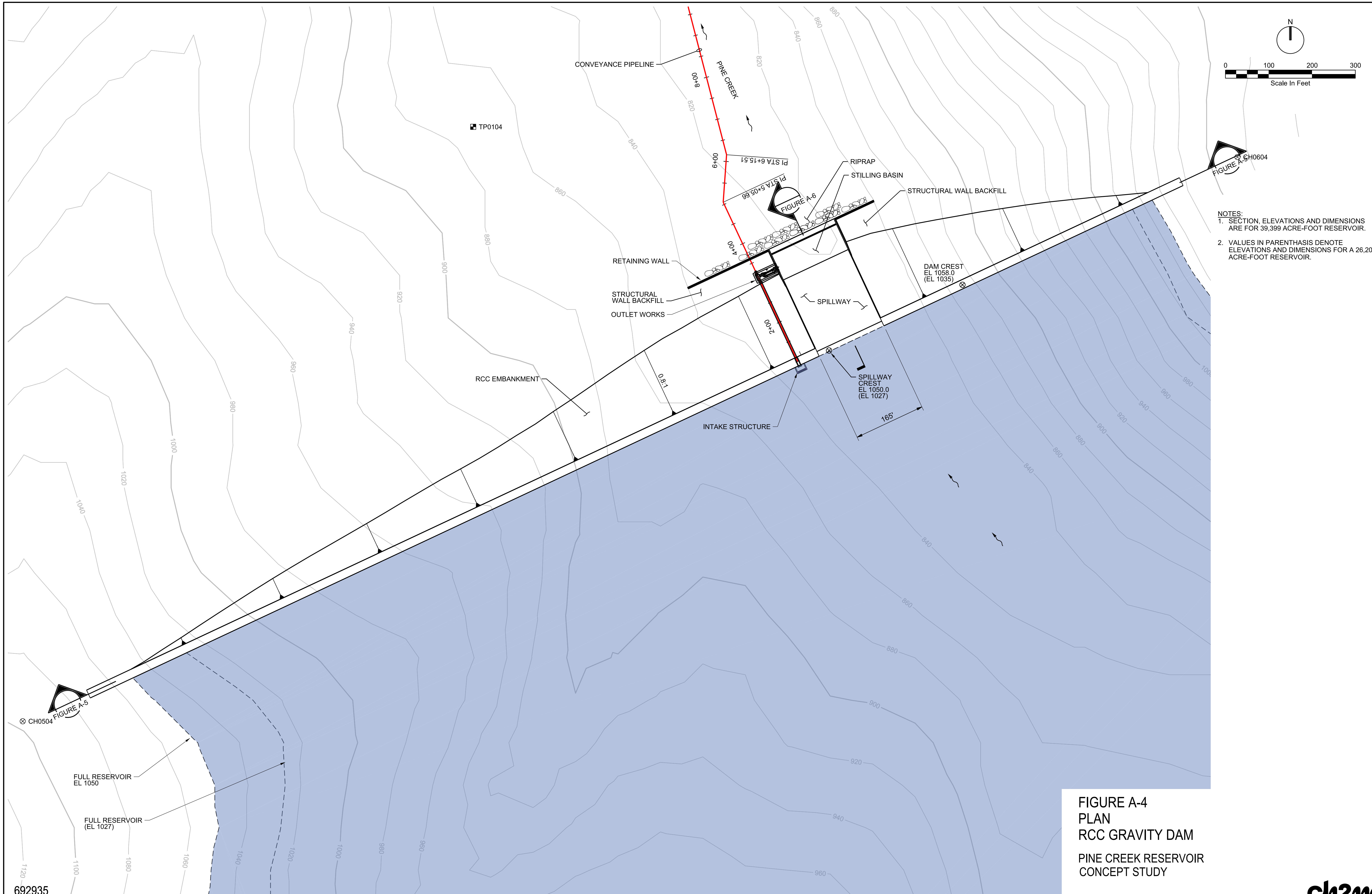


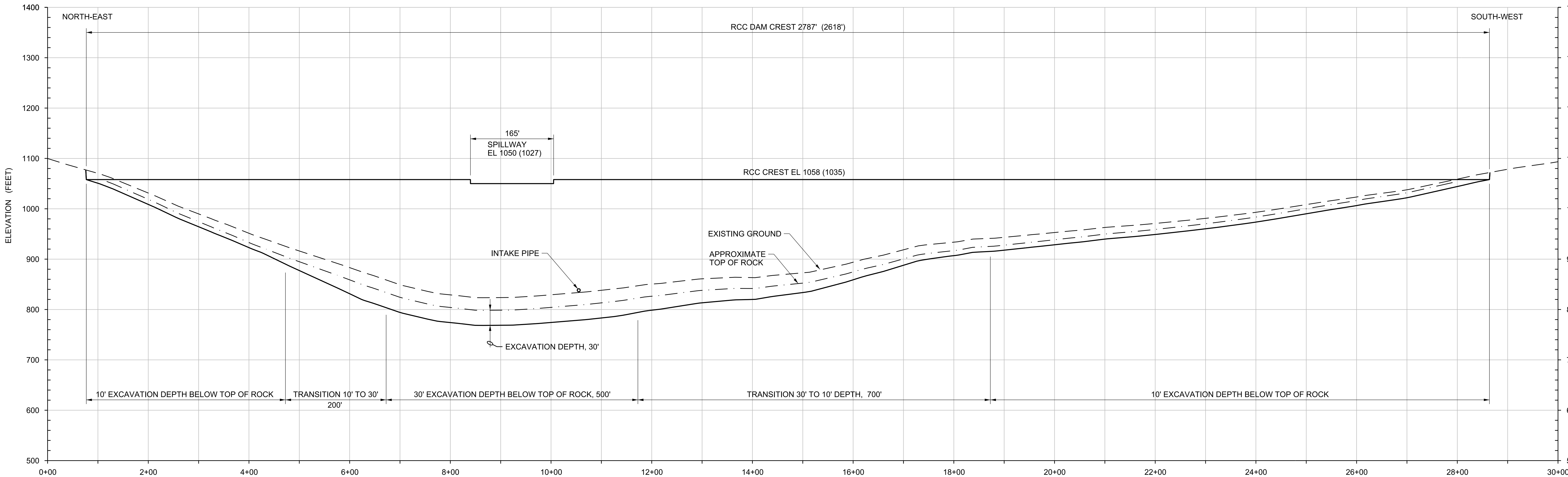
FIGURE A-4
PLAN
RCC GRAVITY DAM

PINE CREEK RESERVOIR
CONCEPT STUDY

ch2m

FILENAME: PC-FigA-4_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 2:34:30 PM

NOTES:
1. SECTION, ELEVATIONS AND DIMENSIONS ARE FOR 39,399 ACRE-FOOT RESERVOIR.
2. VALUES IN PARENTHASIS DENOTE ELEVATIONS AND DIMENSIONS FOR A 26,200 ACRE-FOOT RESERVOIR.



RCC GRAVITY DAM CENTERLINE PROFILE

1"=100'

FIGURE A-5
CENTERLINE PROFILE
RCC GRAVITY DAM

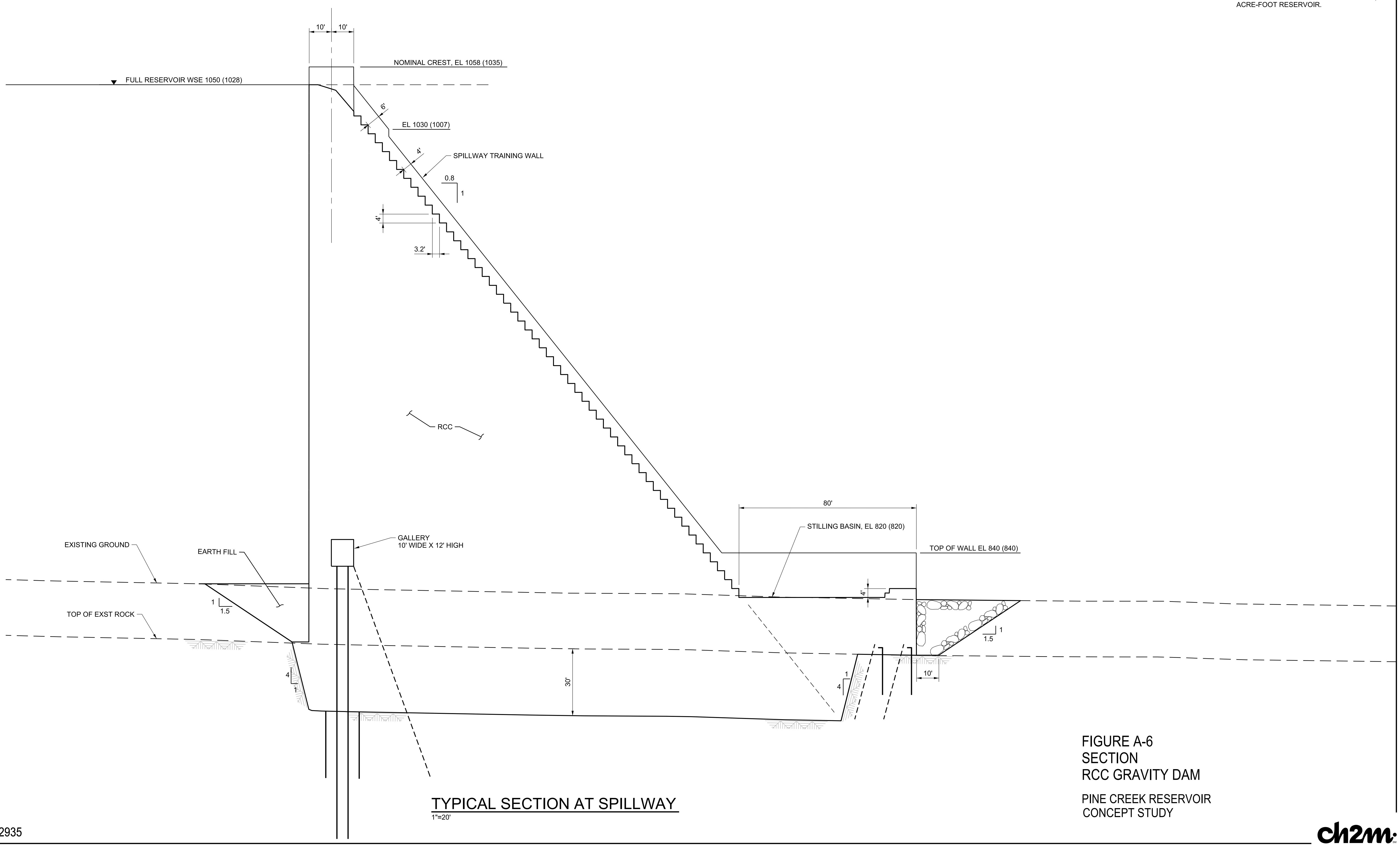
PINE CREEK RESERVOIR
CONCEPT STUDY

692935

ch2m

FILENAME: PC-FigA-5_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 2:34:26 PM

NOTES:
1. SECTION, ELEVATIONS AND DIMENSIONS ARE FOR 39,399 ACRE-FOOT RESERVOIR.
2. VALUES IN PARENTHASIS DENOTE ELEVATIONS AND DIMENSIONS FOR A 26,200 ACRE-FOOT RESERVOIR.



TYPICAL SECTION AT SPILLWAY

1"=20'

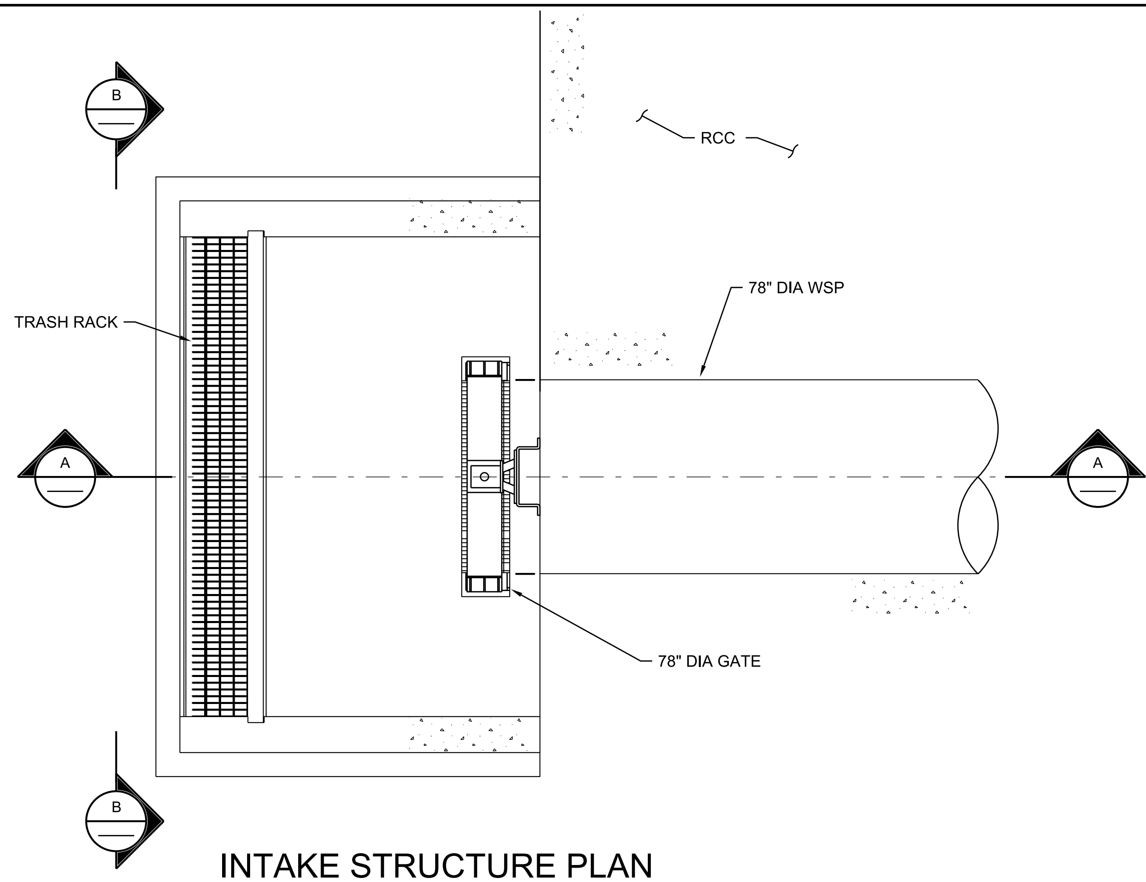
FIGURE A-6
SECTION
RCC GRAVITY DAM

PINE CREEK RESERVOIR
CONCEPT STUDY

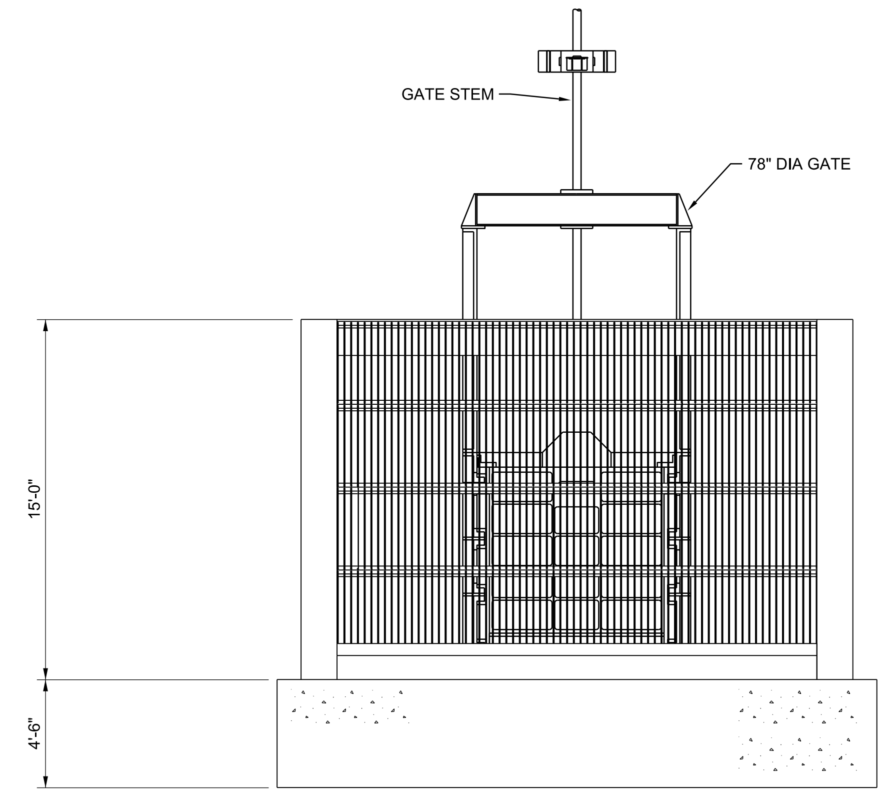
692935

ch2m

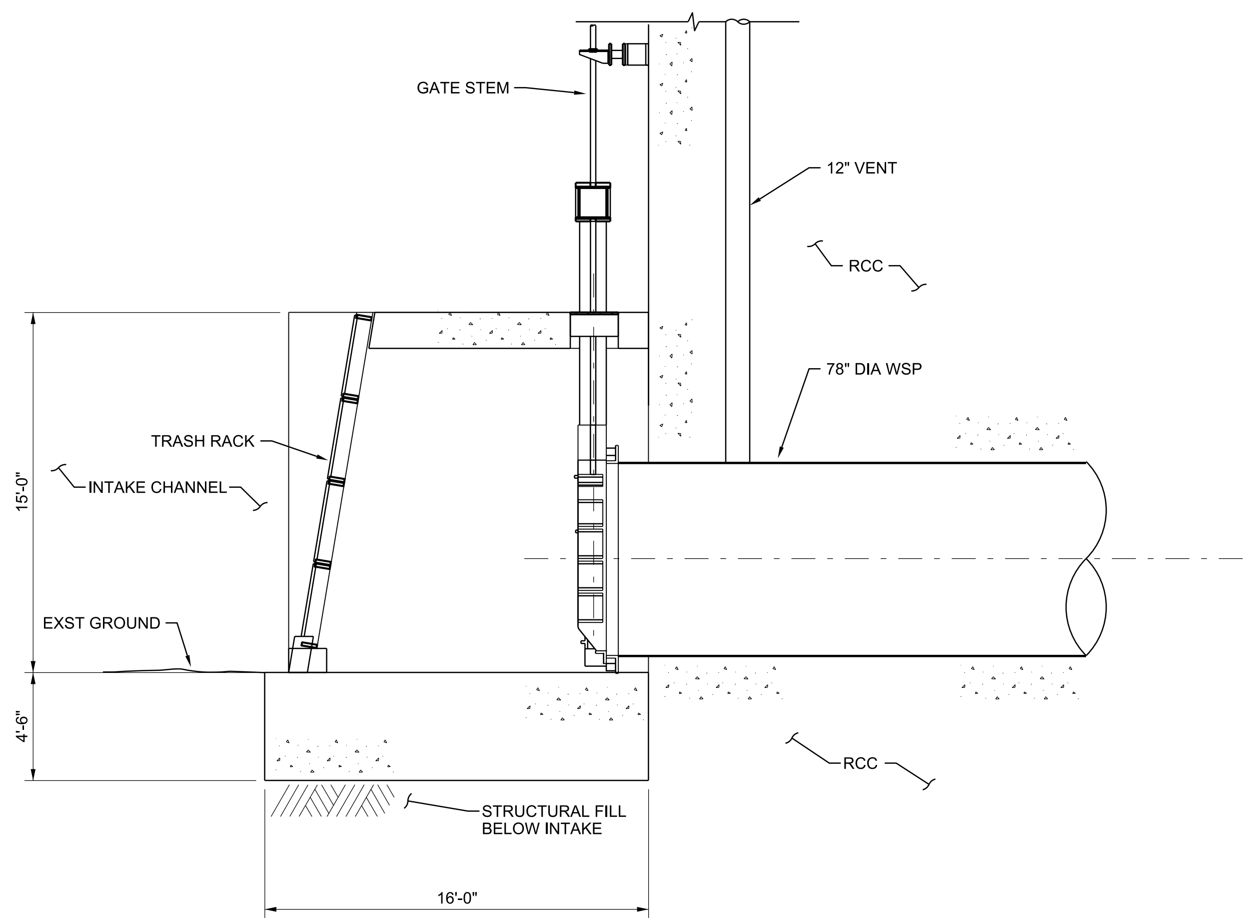
FILENAME: PC-FigA-6_692935.dgn
PC-FigA-6_692935.dgn
PLOT DATE: 8/28/2017
PLOT TIME: 2:34:29 PM



INTAKE STRUCTURE PLAN
1/4"=1'-0"



B SECTION
1/4"=1'-0"



A SECTION
1/4"=1'-0"

FIGURE A-7
INTAKE STRUCTURE
RCC GRAVITY DAM

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

ch2m.

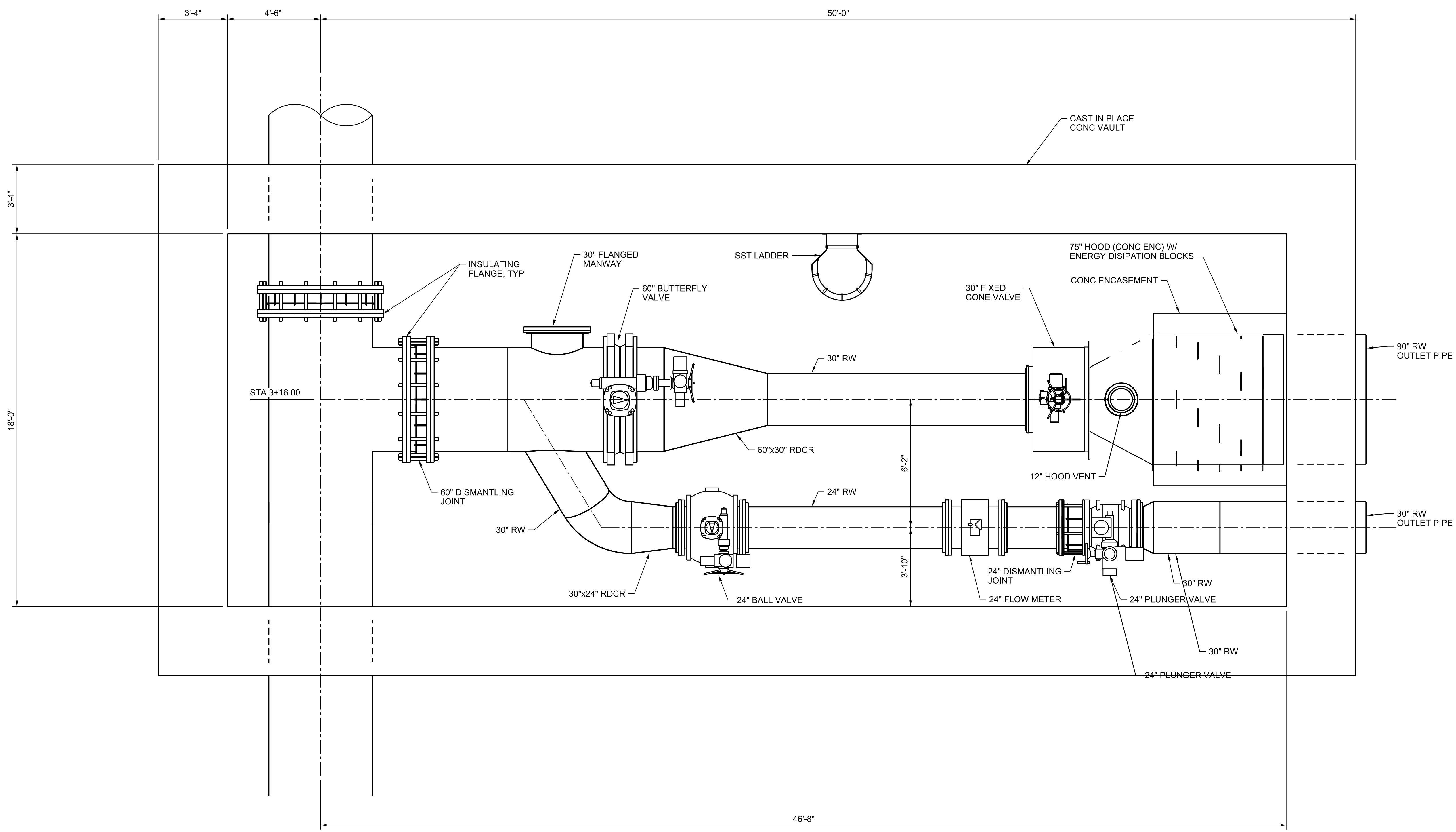
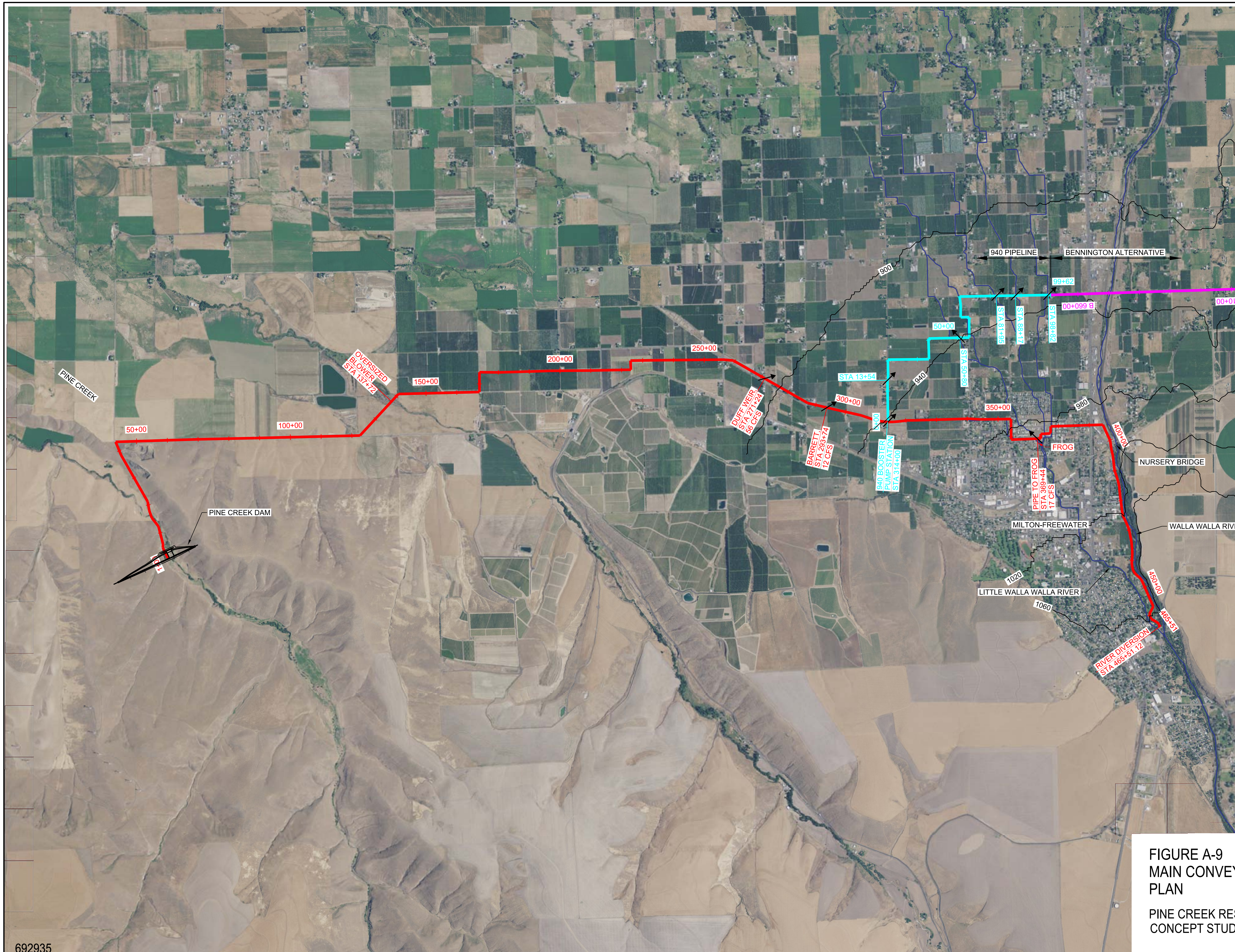


FIGURE A-8
OUTLET WORKS
RCC GRAVITY DAM

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

ch2m:



N

0 1500 3000 4500
Scale In Feet

LEGEND:

- MAIN CONVENANCE ROUTE
- 940 PIPELINE ROUTE
- BENNINGTON ALTERNATIVE
- LOWDEN PIPELINE ROUTE
- HYDROLOGY
- TURNOUT LOCATION

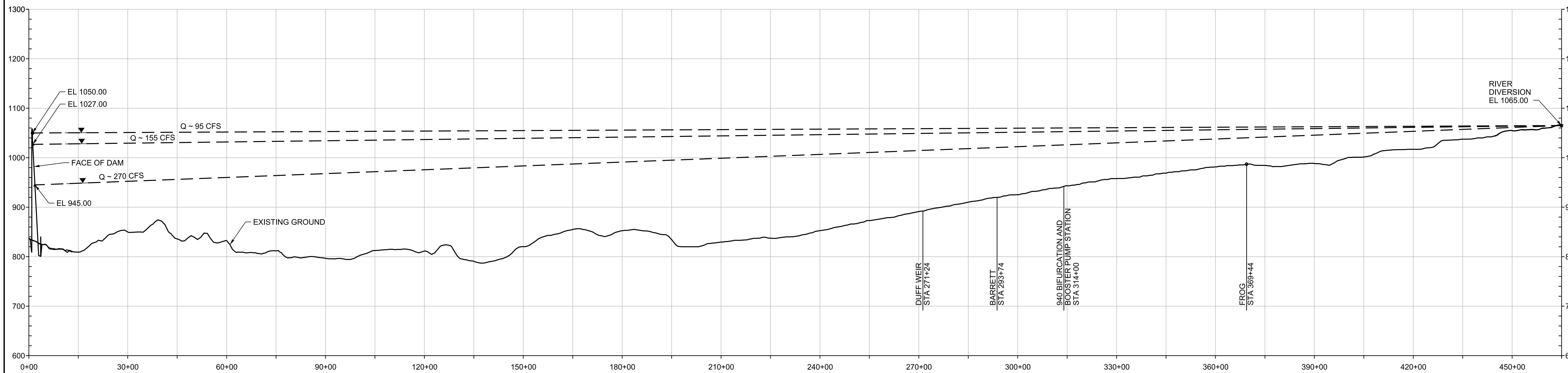
TURNOUT	Q (CFS)
0	14
1354	8
5080	4
8195	3
8817	2
9882	5
BARRETT	12
DUFF WEIR	56
FROG	17

FIGURE A-9
MAIN CONVEYANCE AND DISTRIBUTION PLAN

PINE CREEK RESERVOIR
CONCEPT STUDY

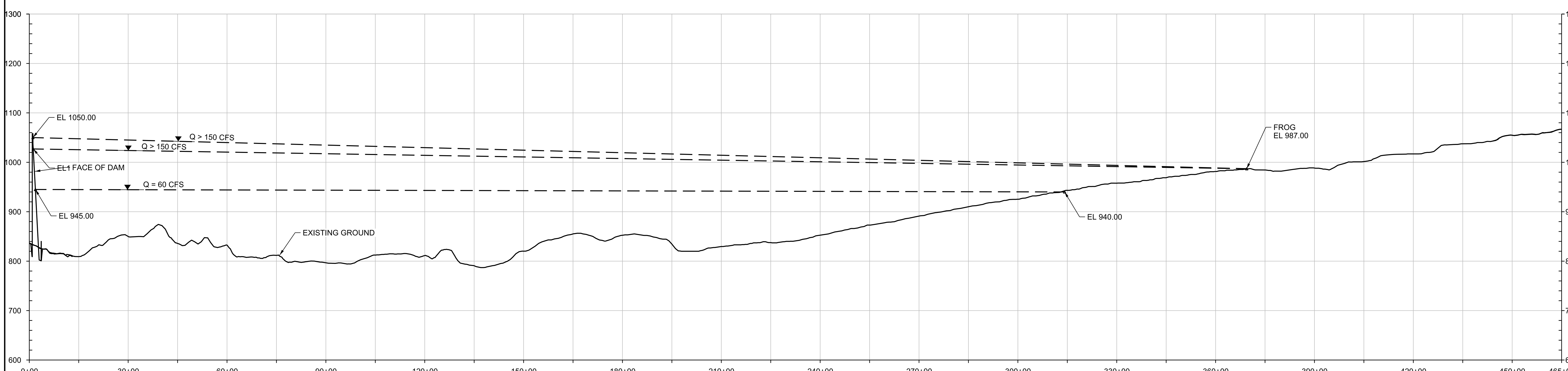
ch2m:

FILENAME: PC-FigA-9_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 4:14:48 PM



MAIN PROFILE FROM PINE CREEK DAM TO CEMETERY (FILLING)

1"=3000' HORIZ
1"=200' VERT



MAIN PROFILE FROM PINE CREEK DAM TO CEMETERY (IRRIGATION DELIVERIES)

1"=3000' HORIZ
1"=200' VERT

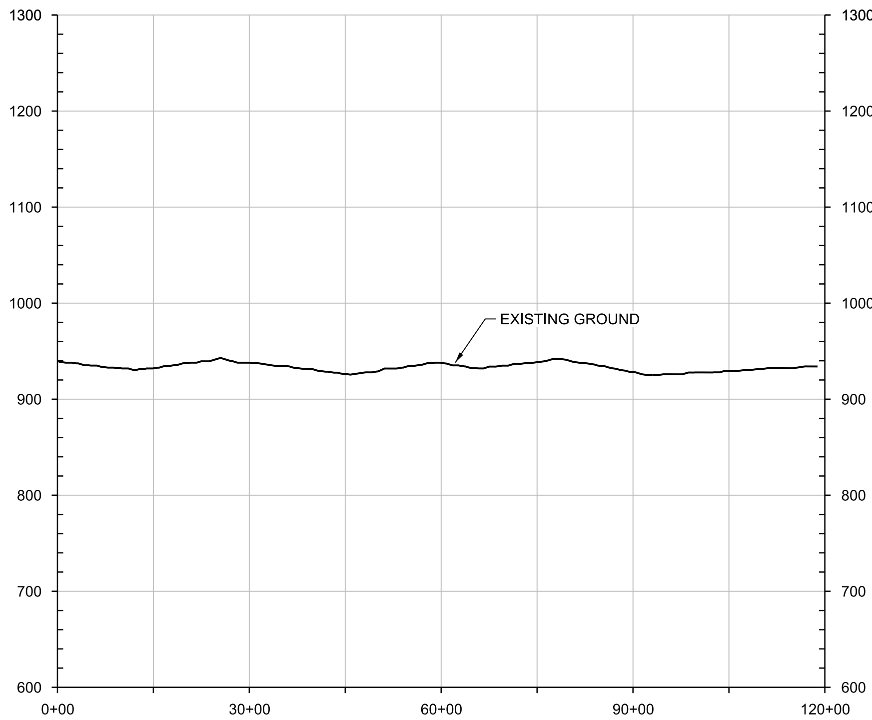
FIGURE A-10
MAIN CONVEYANCE AND DISTRIBUTION
RESERVOIR TO POD PROFILE

PINE CREEK RESERVOIR
CONCEPT STUDY

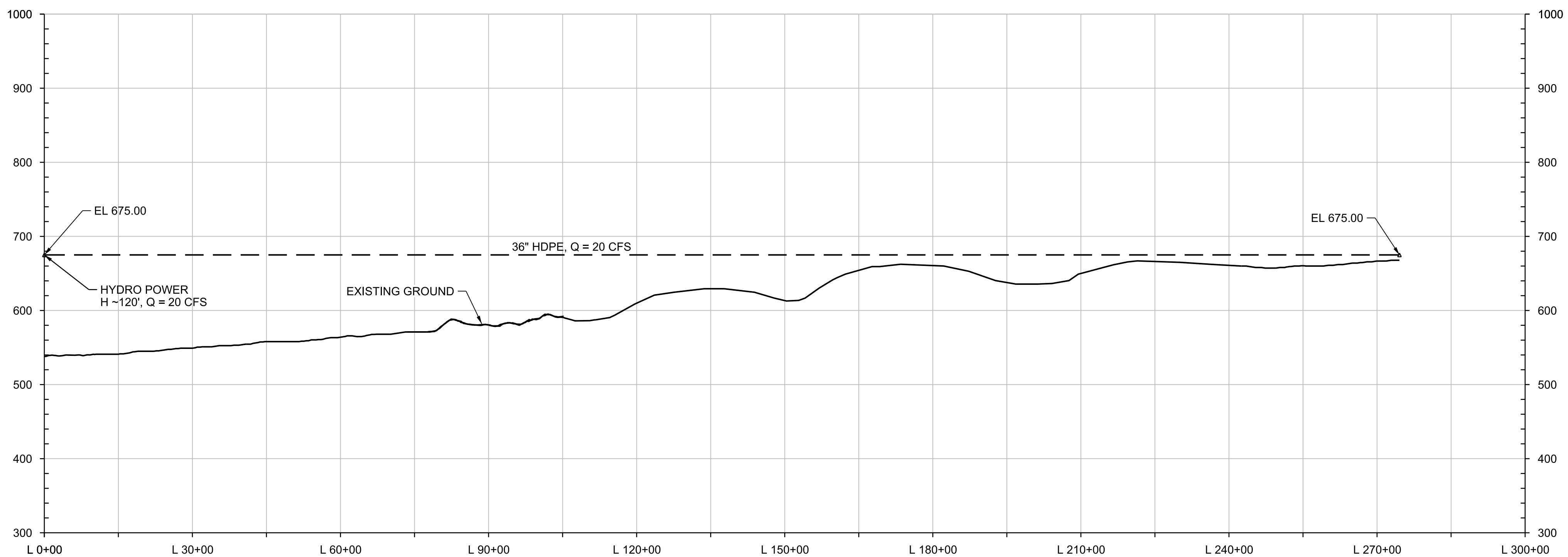
692935

ch2m

FILENAME: PC-FigA-10_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 3:18:00 PM
PC-FigA-10_692935.dgn



PROFILE ALONG ELEVATION 940
1"=3000' HORIZ
1"=200' VERT



PROFILE FROM LOWDEN
1"=3000' HORIZ
1"=200' VERT

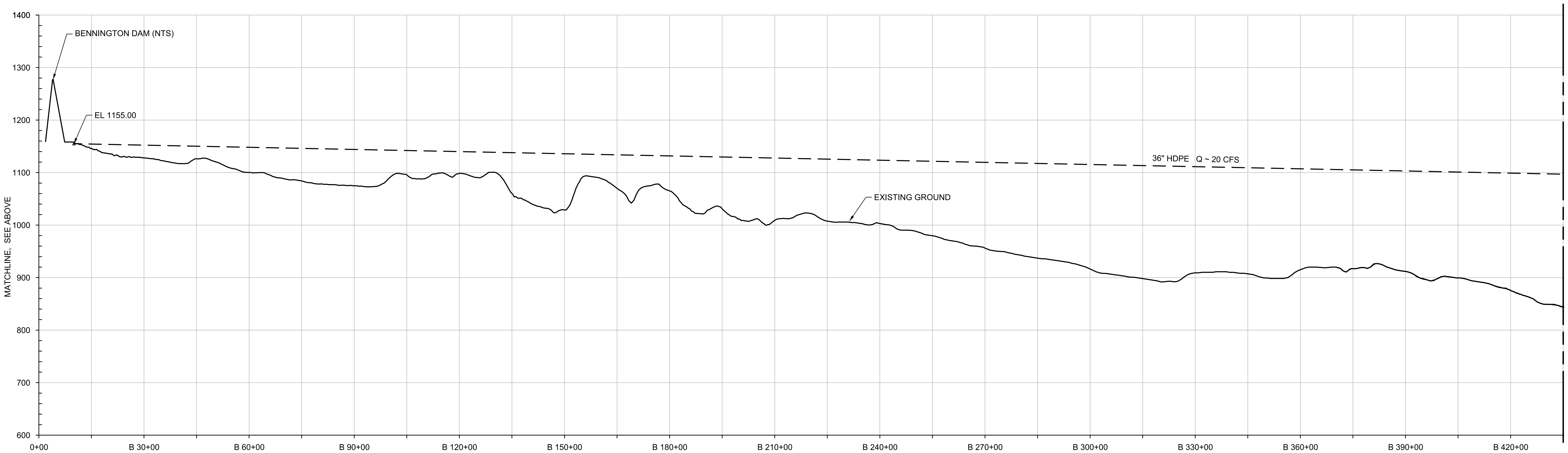
FIGURE A-11
MAIN CONVEYANCE AND DISTRIBUTION
DISTRIBUTION PROFILES

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

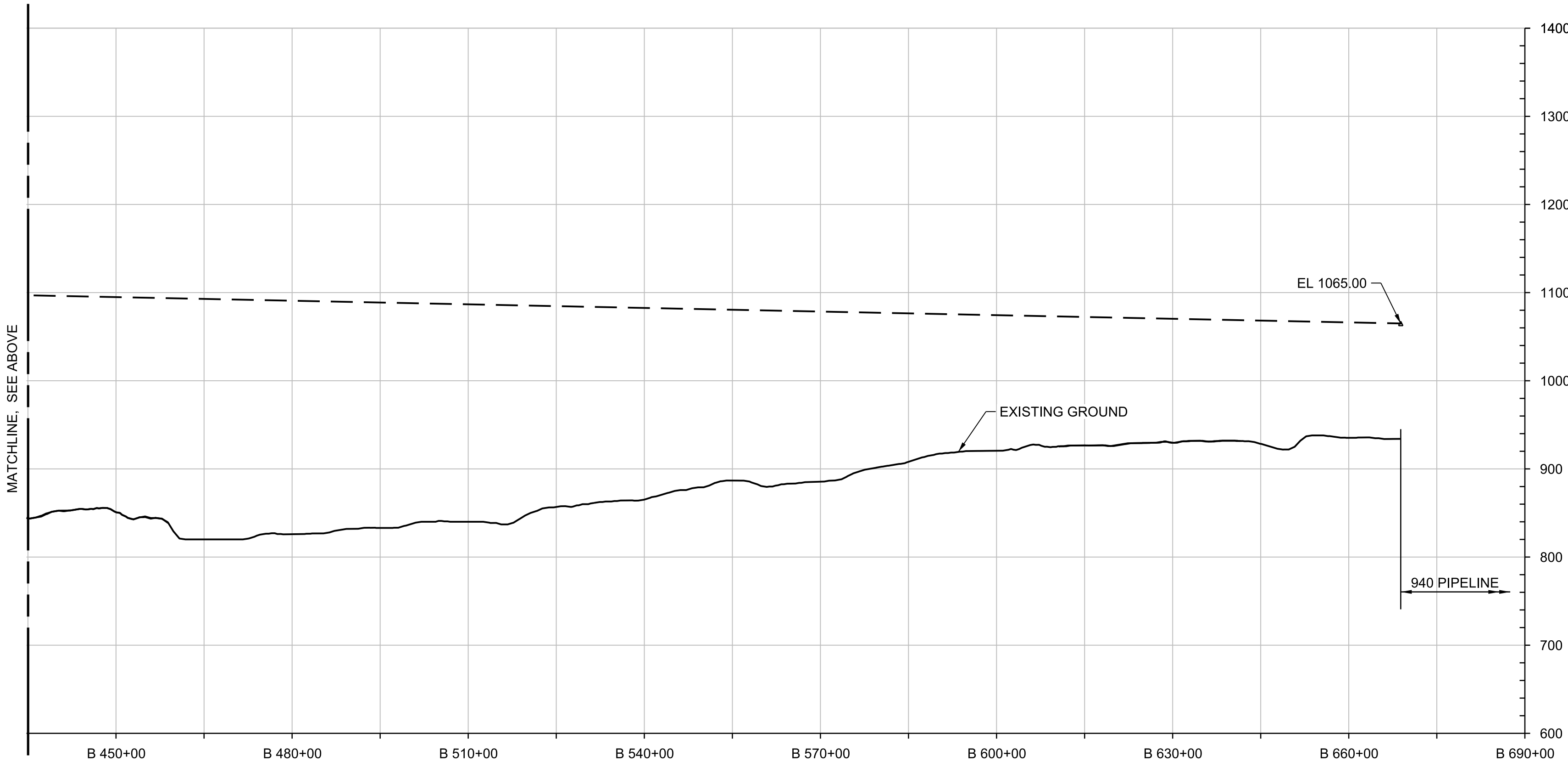
ch2m

FILENAME: PC-FigA-11_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 3:35:27 PM



PROFILE - BENNINGTON

1"=3000' HORIZ
1"=200' VERT



PROFILE - BENNINGTON (CONTINUED)

1"=3000' HORIZ
1"=200' VERT

FIGURE A-12
BENNINGTON
CONVENANCE PROFILE

PINE CREEK RESERVOIR
CONCEPT STUDY

692935

ch2m

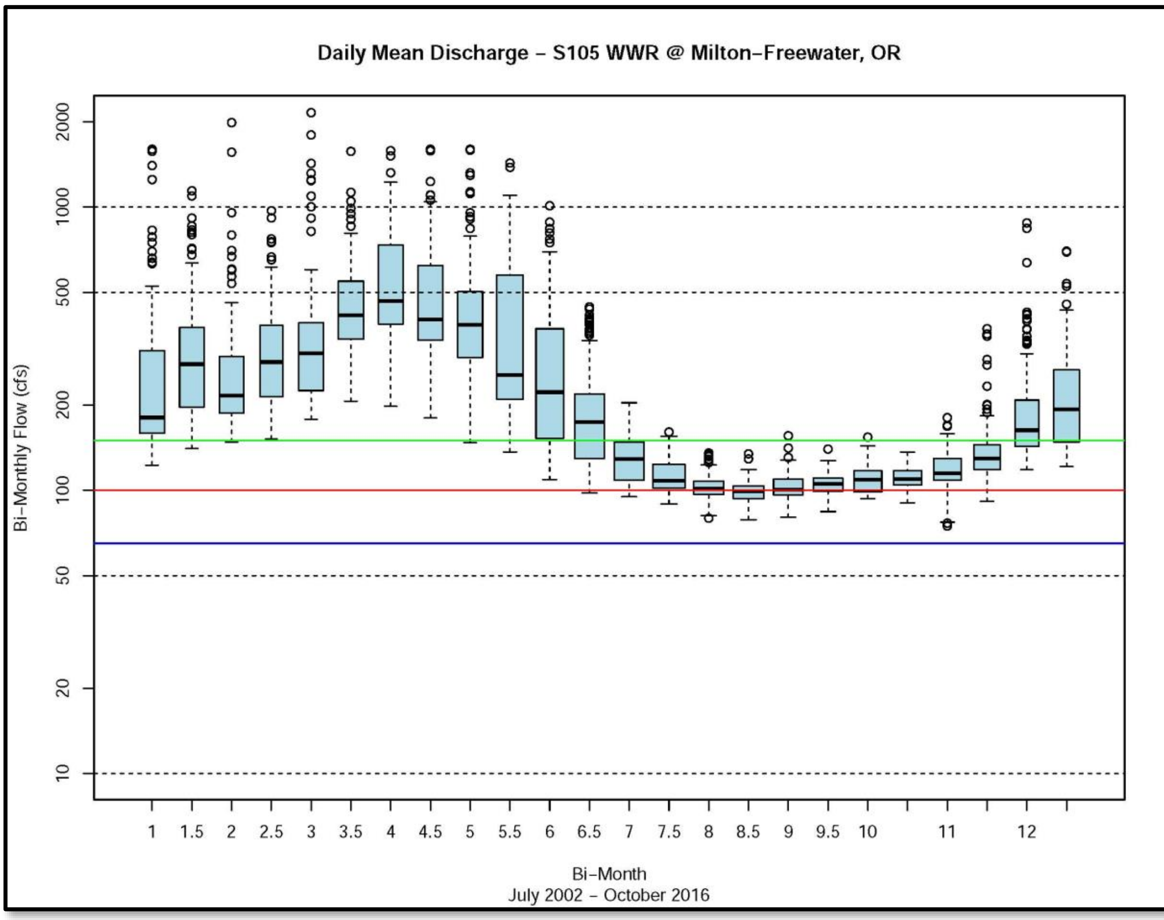
FILENAME: PC-FigA-12_692935.dgn PLOT DATE: 8/28/2017 PLOT TIME: 3:18:18 PM

Appendix B
Hydrology Memorandum

Walla Walla Basin Watershed Council

Walla Walla Basin Flow Analysis

Data Analysis Methods Supporting the Walla Walla Basin Integrated Flow Enhancement Study



FINAL REPORT

August 2017

Walla Walla Basin Flow Analysis

Data Analysis Methods Supporting the Walla Walla Basin Integrated Flow Enhancement Study

Written by:

Steven Patten, Senior Environmental Scientist, WWBWC

Walla Walla Basin Watershed Council

2017

Report available at www.wwbwc.org

Contents

20% Reservoir Diversion

30% Reservoir Diversion

INTRODUCTION

The Walla Walla River and its tributaries provide for agricultural production, support thriving communities, and sustain resident and anadromous fish populations. As in many western river basins, instream and out-of-stream water demands often exceed available supplies. The Walla Walla Watershed Management Partnership (WWWMP) and the Walla Walla Basin Watershed Council (WWBWC) convened a Steering Committee to develop strategies to meet instream needs. Washington Department of Ecology, Oregon Water Resources Department, Oregon Department of Environmental Quality and Bonneville Power Administration have provided funding for the Walla Walla Basin Stream Flow Enhancement Study (the Study).

The Study intends to identify strategies to meet instream flow demands while addressing out-of-stream municipal and agricultural needs. Objectives include restoring Walla Walla River stream flows to the magnitude necessary to support harvestable populations of native fish species and providing certainty to water right holders that their needs will be met. Study Partners convened a Steering Committee consisting of tribal, state, and local governments, as well as irrigation, municipal, and recreational interests to guide the development of these strategies. The steering committee strives for consensus basis decision-making, which helps inform the Study Partners as they adopt final decisions.

The Steering Committee focused on restoring stream flows in the Walla Walla River from the Little Walla Walla River point of diversion at Cemetery Bridge in Milton-Freewater, OR to the confluence of the Walla Walla and Columbia Rivers, and the committee agreed by consensus to instream flow targets in this reach of the Walla Walla River (Table 1 and Figure 1).

Table 1. Interim Stream Flow Targets for the Walla Walla River in cubic feet per second (cfs)

Time Period	Hybrid Flow Targets
April 1 – June 15	150 cfs
June 16 – June 30	100 cfs
July 1 – November 30	65 cfs

The Steering Committee identified and evaluated a wide range of strategies intended to meet these stream flow targets, including conservation, increasing aquifer recharge, developing large-scale reservoirs, and pumping water from the Columbia River. In order to evaluate these strategies, the Steering Committee assembled the following Technical Workgroups (TWGs), whose function was to evaluate the timing, location, magnitude, costs and benefits of proposed flow improvement strategies:

- Water Conservation and Infrastructure (Washington)
- Water Conservation and Infrastructure (Oregon)
- Managed Aquifer Recharge (MAR)/Aquifer Storage and Recovery (ASR)
- Surface Water Storage
- Columbia River Pump Exchange
- Water Right Transactions and Management
- Legal
- Planning

Each of the TWG's were chartered by the Steering Committee to:

1. Develop potential project lists or strategies to meet Flow Study goals;
2. Develop and document a screening process to reduce the list to priority efforts with the greatest likely feasibility in meeting Flow Study goals;
3. Provide a prioritized list of projects for completion of "Project Proposal Templates"; and
4. Participate in a "project pairing" evaluation with the Steering Committee to assemble a preferred alternative of projects designed to meet Flow Study goals.

Based on this planning framework, the Steering Committee is working to develop a consensus recommendation of projects that collectively meet the flow target goals of the Study (Table 1).

As work progressed on project development in the TWG's, a need for additional flow analysis was identified for many, if not all, of the proposed projects. The WWBWC, working with other TWG members and sub-contractors, started a preliminary analysis of flow data as required by various projects.

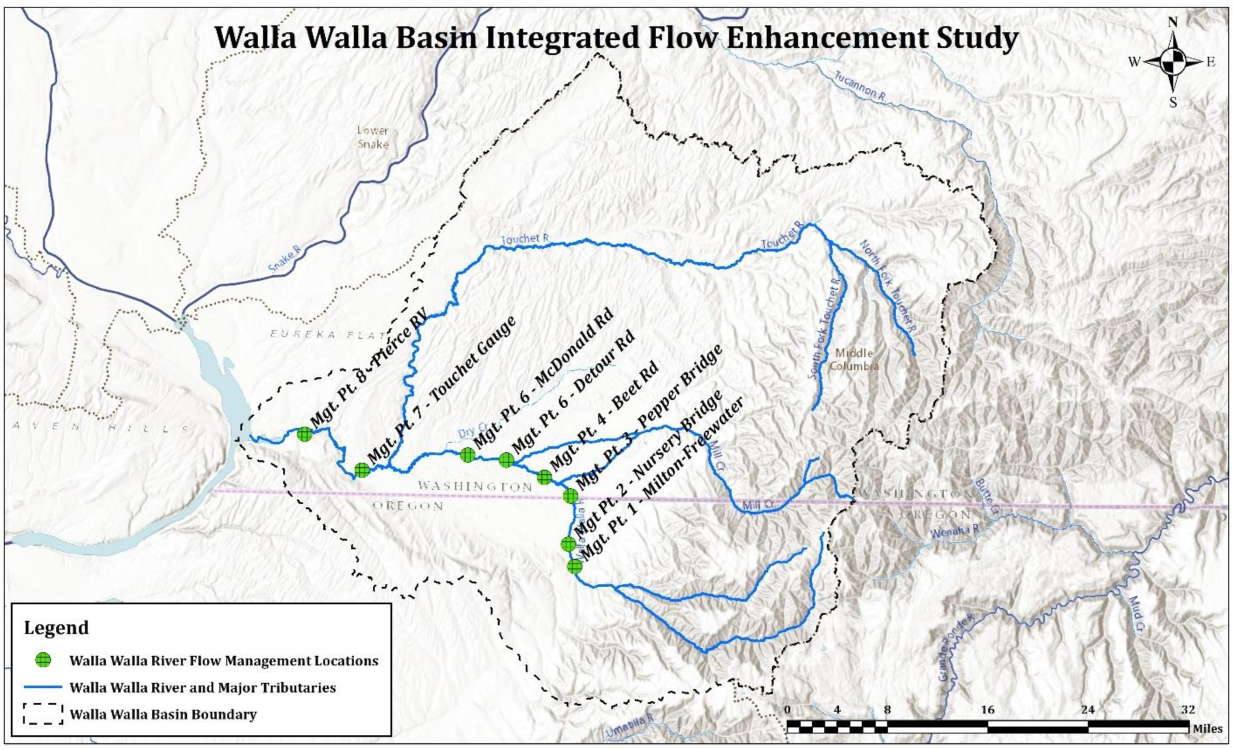


Figure 1 - Map of the Walla Walla Basin indicating flow management locations for the Walla Walla Basin Integrated Flow Enhancement Study.

PURPOSE

The purpose of this report is to document the methods of analysis and the results conducted for various projects within the Walla Walla Basin Integrated Flow Enhancement Study.

FLOW ANALYSIS METHODS & RESULTS

CURRENT INSTREAM FLOW ANALYSIS

The need to quantify current instream flow values, at each of the management points for the Study (Figure 1), was identified by multiple TWG's as projects were being investigated. Period of record for each gauge location is different (see Table 2). Most gauges were installed after the Settlement Agreement in 2000 where three irrigation districts agreed to by-pass 13 cfs in 2000, 18 cfs in 2001, then either either 25/27 cfs at Milton-Freewater or 18/19 cfs at Beet Road to benefit threatened fish species under the Endangered Species Act (ESA).

Table 2. Period of record used for flow analysis at management location gauges on the Walla Walla River (WWR)

Gauge Name/Management Location	Agency	Period of Record
WWR @ Milton-Freewater	WWBWC	2002-2009 (Seasonal) 2009-2016 (Permanent)
WWR @ Below Nursery Bridge (M4)	WWBWC	2002-2016 (Seasonal)
WWR @ Pepper Bridge (Stateline)	WDOE/WWBWC	2004-2012 (Operated by WDOE) 2012-2016 (Operated by WWBWC)
WWR @ Beet Road	WDOE	2002-2016
WWR @ Detour Road	WDOE	2006-2016
WWR @ McDonald Road	WWBWC	2013-2016
WWR @ Below Touchet River	USGS	1951-2016
WWR @ RV Park	WWBWC	2013-2016

Available gauge data was converted into daily average flow, if not already in that format. Data were formatted into a common format (tab delimited text files). R, the statistical computing and graphics program, was utilized to process and compute bi-monthly exceedance flow values from the daily average data (see Appendix A for code info). Basics descriptive statistics of inputted data were conducted as a quick QA/QC of data (e.g. no extremely low/high values or unexpected data gaps). Data were aggregated by bi-month (see Table 3). Minimum, average, maximum, variance, sample size and exceedance values (10%, 25%, 50%, 75%, and 90%) were generated for each bi-month period (Table 4 & Appendix B). Bi-monthly data represents either days 1-15 or days 16-end of the month. The bimonthly data allows for better resolution of flow data as stream flows drop in the late spring/early summer and rise in the late fall.

Table 3. Bimonthly nomenclature used for Current Instream Flow Analysis

Date	Month	Bi-month
January 1-15	1	1
January 16-31	1	1.5
February 1-15	2	2
February 16-28/29	2	2.5
March 1-15	3	3
March 16-31	3	3.5
April 1-15	4	4
April 16-30	4	4.5
May 1-15	5	5
May 16-31	5	5.5
June 1-15	6	6
June 16-30	6	6.5
July 1-15	7	7
July 16-31	7	7.5
August 1-15	8	8
August 16-31	8	8.5
September 1-15	9	9
September 16-30	9	9.5
October 1-15	10	10
October 16-31	10	10.5
November 1-15	11	11
November 16-30	11	11.5
December 1-15	12	12
December 16-31	12	12.5

Table 4. Example of generated bimonthly aggregated data with minimum, maximum, average, variance, sample size and exceedances.

S-105 - Walla Walla River @ Milton-Freewater, OR

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size.N
1	122.73	180.76	1600.00	294.97	141.86	159.21	180.76	310.18	536.17	74826.60	110
1.5	140.43	278.75	1141.50	342.30	167.22	198.69	278.75	375.71	634.27	43227.59	104
2	147.89	215.66	1987.49	299.23	175.59	187.20	215.66	296.66	450.87	64002.50	103
2.5	151.76	283.85	970.99	330.05	175.38	214.38	283.85	382.25	571.47	29704.41	91
3	178.25	304.38	2154.32	398.55	187.21	224.95	304.38	390.65	732.86	112274.17	105
3.5	206.14	414.82	1572.55	472.20	290.63	341.90	414.82	546.06	708.94	44269.73	112
4	197.93	465.59	1581.63	555.11	262.85	385.93	465.59	734.85	892.68	76100.79	105
4.5	180.12	400.80	1600.00	504.35	199.14	338.88	400.80	614.43	858.54	89582.03	104
5	147.42	384.09	1600.00	467.62	173.11	294.13	384.09	503.03	867.04	102475.21	107
5.5	136.61	255.40	1430.46	382.35	150.54	209.75	255.40	575.55	745.40	75548.62	119
6	108.93	222.05	1011.05	283.79	127.48	152.46	222.05	371.88	497.13	32627.12	131
6.5	97.84	174.02	444.33	191.58	108.16	129.38	174.02	218.47	321.62	6825.28	150
7	94.89	129.09	203.84	130.22	101.32	108.44	129.09	148.24	164.15	638.29	150
7.5	89.62	108.30	160.63	113.16	96.92	101.70	108.30	123.61	141.04	270.73	175
8	79.73	101.39	135.42	103.07	92.85	96.81	101.39	107.48	117.58	122.50	158
8.5	78.77	99.10	134.53	99.03	87.77	93.49	99.10	103.75	110.31	84.66	160
9	80.40	100.56	155.81	102.30	89.17	96.37	100.56	109.40	113.47	122.15	150
9.5	84.11	105.28	139.84	104.72	93.40	99.17	105.28	110.56	114.13	81.18	150
10	93.46	109.22	154.04	109.79	96.59	98.95	109.22	117.22	123.53	133.29	135
10.5	90.26	109.64	136.54	110.98	100.96	104.39	109.64	117.48	121.60	76.74	137
11	74.84	114.73	180.55	118.37	99.74	108.64	114.73	129.71	143.97	372.70	131
11.5	91.34	129.69	372.17	140.13	106.84	118.49	129.69	144.58	179.95	2174.18	120
12	118.33	162.93	879.42	210.66	124.01	143.13	162.93	208.21	353.50	17249.04	99
12.5	121.28	193.14	698.95	227.50	123.98	148.31	193.14	266.31	364.34	12149.11	112

Fifty percent exceedance (50% quantile) values were used to build the "Walla Walla River Exchange Model" developed by Anton Chiono and others at the Confederated Tribes of the Umatilla Indian Reservation (CTUIR).

Results for each of the management locations (Table 2) are included in Appendix B.

Reservoir Storage Water Analysis

A reassessment of the Pine Creek Reservoir is one of the primary projects being investigated in the Study. As part of the reassessment, reservoir engineers requested updated flow data for a variety of rivers and creeks in the Walla Walla Basin to make an initial determination on the volume of water available for filling the reservoir. The effort resulted in the creation of a spreadsheet that includes daily average data for 13 gauge locations, calculated/extrapolated data sets for 3 creek systems and a variety of graphical and statistical analysis.

Stream Gauge Datasets and Period of Records

Figure 2 illustrates stream gauge data and periods of record utilized for the reservoir storage water analysis.

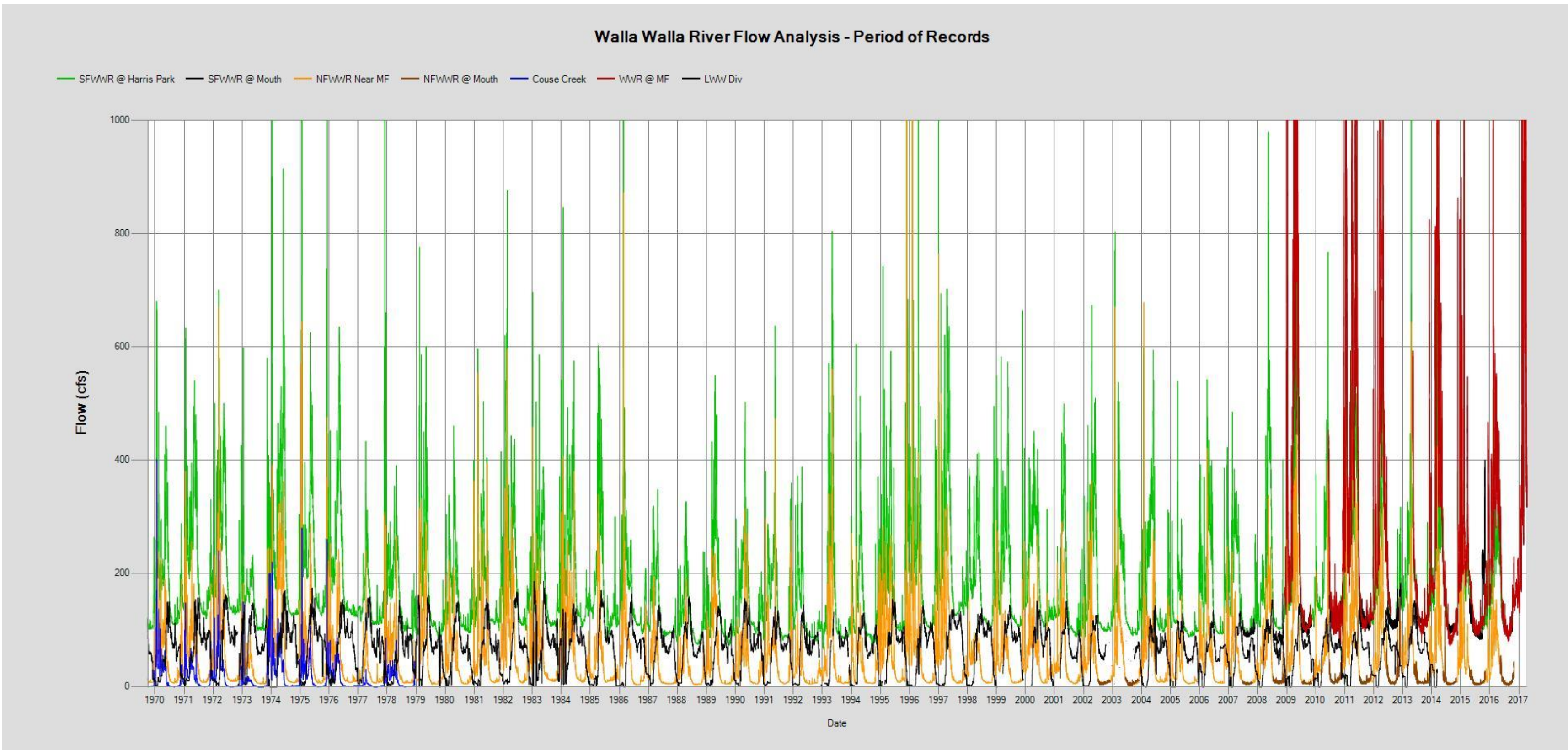


Figure 2 - Hydrograph for stream gauges utilized in the reservoir storage water analysis - 1970-2016.

Walla Walla River Composite Dataset

A composite dataset was created for flows upstream of the point of diversion for the proposed reservoir (Little Walla Walla River POD located at Cemetery Bridge in Milton-Freewater, OR). Flow above the POD includes the South Fork Walla Walla River, North Fork Walla Walla River and Couse Creek. The South and North Forks have gauge data from 1969 to present, however Couse Creek only has gauge data from 1964-1978. The Walla Walla River @ Milton-Freewater gauge has a period of record of 2009-2016, which does not provide enough data for robust analysis. A composite dataset was created by adding the North and South Fork gauges to a derived Couse Creek dataset.

The composite Walla Walla River dataset was calculated by adding daily average flow for the North Fork Walla Walla River, South Fork Walla Walla River and derived Couse Creek.

Couse Creek Derived Dataset

The derived Couse Creek dataset was created by using existing gauge data where available. A correlation between Couse Creek and North Fork Walla Walla River flows was created for the periods where no Couse Creek gauge data was available. Monthly correlations were used to create variable coefficients. North Fork Walla Walla River flow data was multiplied by the monthly variable coefficients to calculate missing Couse Creek flow data.

*Derived Couse Creek Flow = North Fork WWR flow * Monthly Variable Coefficient*

Table 5. Monthly variable coefficients for calculating missing Couse Creek flow from North Fork Walla Walla River flow data.

Month	Variable Coefficients
October	0.05
November	0.28
December	0.37
January	0.37
February	0.37
March	0.37
April	0.30
May	0.25
June	0.13
July	0.06
August	0.07
September	0.04

Derived Couse Creek data was graphed with OWRD's Couse Creek gauge data from 1969-1978 and the derived Couse Creek data from the US Army Corps of Engineer's Study (See Walla Walla River Basin No Action Report- Appendix A Hydrology – 2013). The derived Couse Creek dataset is comparable to the dataset created by the US Army Corps of Engineers (USACOE). However, this dataset indicates lower flow values for high flow events compared to the USACOE dataset (Figure 3).

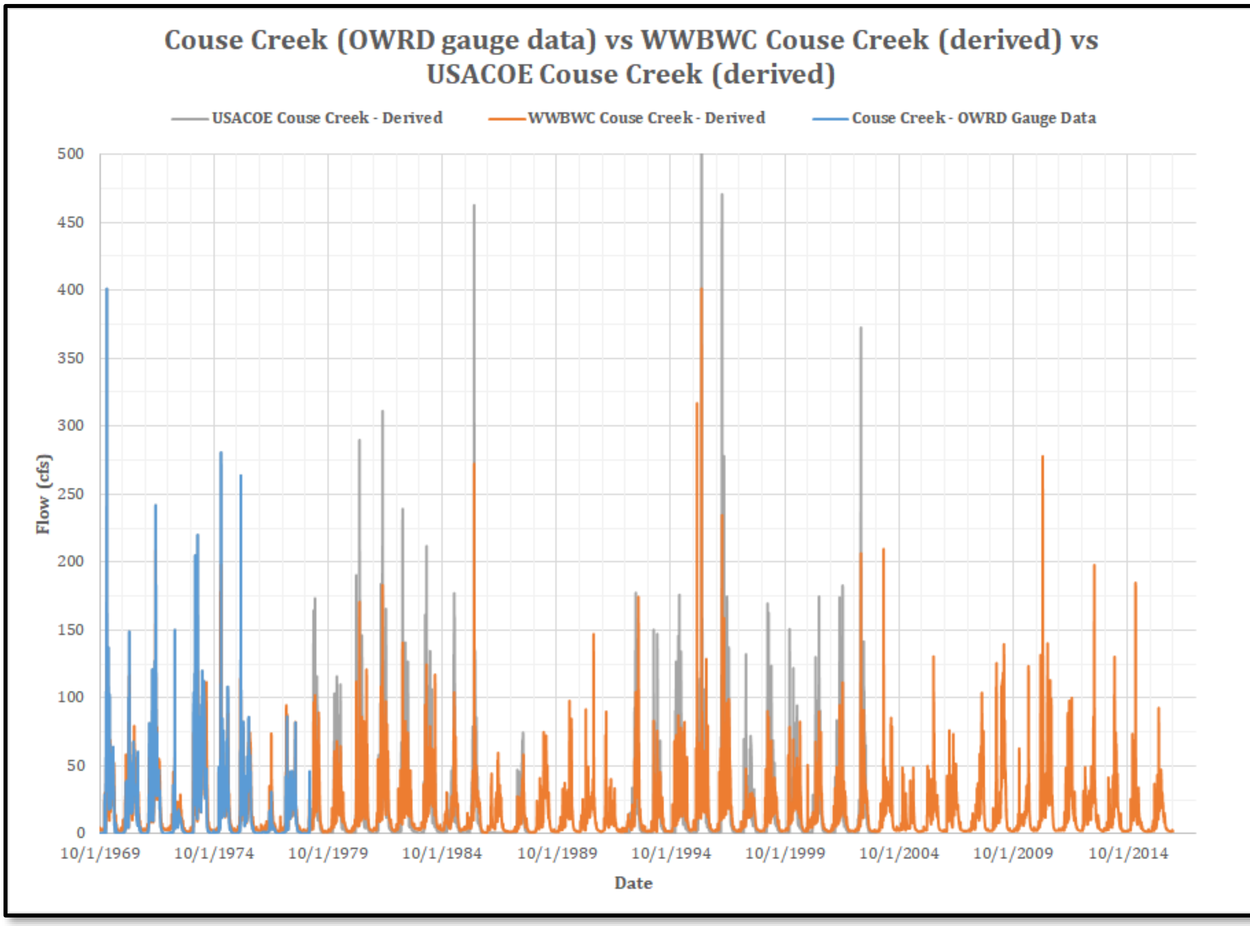


Figure 3 - Hydrograph of Couse Creek datasets. Blue line shows OWRD gauge data for Couse Creek from 1969-1978. Orange line shows WWBWC derived dataset for Couse Creek for 1969-2016. Gray line shows USACOE derived dataset for Couse Creek for 1969-2003.

Pine Creek Derived Dataset

Stream flow data for Pine Creekwas collected by OWRD from October 1964 to September 1985. A derived dataset for Pine Creek was created by using existing gauge data where available to expand the Pine Creek dataset. A correlation between Pine Creek and Mill Creek flows was created for the periods where no Pine Creek gauge data was available.

*Derived Pine Creek Flow = Mill Creek @ Kooskooskie flow * 0.2189 + -6.787*

Derived Pine Creek data was graphed with OWRD's Pine Creek gauge data from 1964-1985 and the derived Pine Creek data from the US Army Corps of Engineer's Study (See Walla Walla River Basin No Action Report- Appendix A Hydrology – 2013). The derived Pine Creek dataset is comparable to the dataset created by the US Army Corps of Engineers (USACOE). However, this dataset indicates lower flow values for high flow events compared to the USACOE dataset (Figure 4).

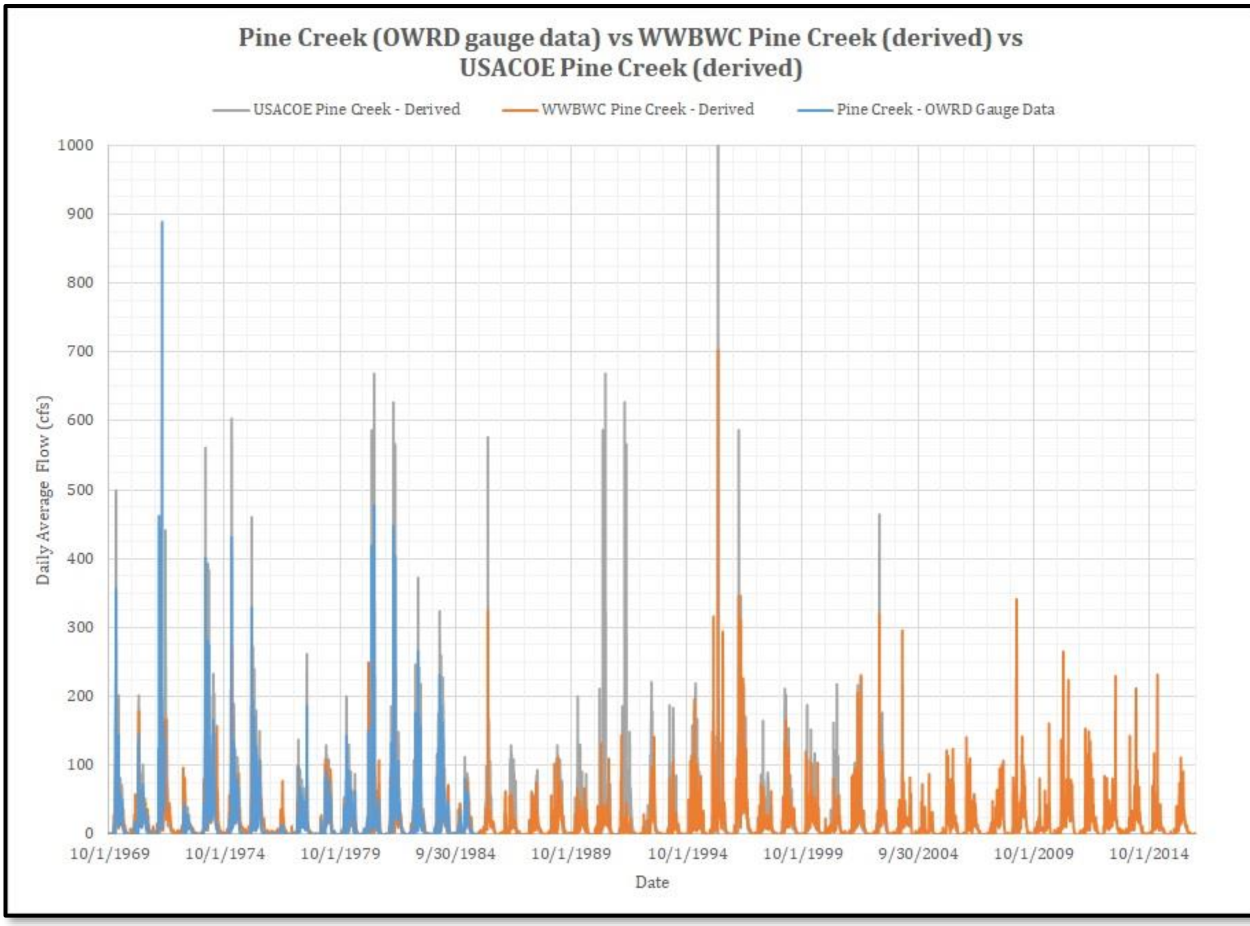


Figure 4 - Hydrograph of Pine Creek datasets. Blue line shows OWRD gauge data for Pine Creek from 1964-1985. Orange line shows WWBWC derived dataset for Couse Creek for 1969-2016. Gray line shows USACOE derived dataset for Couse Creek for 1969-2003.

Mill Creek Composite Dataset

Gauge data for Mill Creek at Kooskooskie exists from 1969 to present, with a data gap from 1976 to 1979. A derived dataset was created for the Mill Creek gauge at Kooskooskie (USGS 14013000) to fill in missing data from October 1, 1976 to October 1, 1979. The derived Mill Creek flow data were created by using a correlation between the North Fork Walla Walla River and Mill Creek flows. The derived data were used where no Mill Creek gauge data was available. The resulting composite dataset was utilized for analysis of water availability in Mill Creek. Derived data for Mill Creek and Mill Creek at Kooskooskie data were graphed for visual comparison (Figure 5).

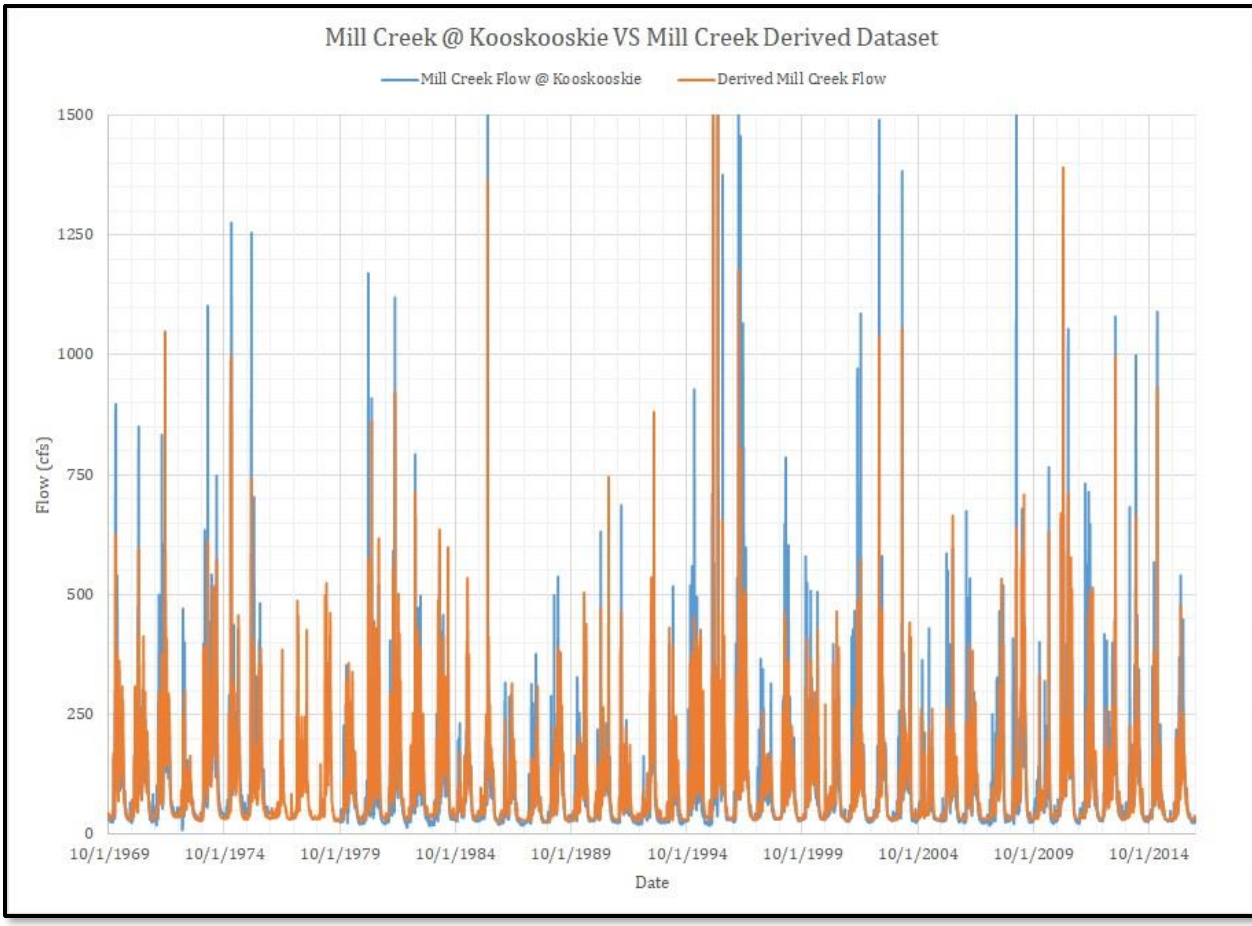


Figure 5 - Hydrograph of flow data from Mill Creek at Kooskooskie gauge (14013000) and derived Mill Creek dataset. Derived dataset was used to fill a data gap in the gauge data from October 1, 1976 to October 1, 1979.

Water Year Ranking Analysis

The Composite Walla Walla River and Pine Creek datasets were analyzed to determine water year ranking. This analysis allows for the determination of "wet" (25% exceedance), "normal" (50% exceedance) and "dry" (75% exceedance) years. Daily average flow was converted into daily volume (acre-feet), which was used to create an annual flow volume for each water year (Oct 1 – Sept 30). Annual flow volumes were then ranked (Tables 6 and 7). Figure 6 illustrates the annual water year ranking in histogram form for the Walla Walla River at Milton-Freewater. Annual flow volumes for the Walla Walla River at Milton-Freewater range from ~55,000 to ~140,000 acre-feet and Figure 7 displays annual ranking over time with a linear trend line. Figures 8 and 9 show the same information for Pine Creek. Annual flow volumes in Pine Creek range from ~3,700 to ~23,000 acre-feet.

Table 6 – Walla Walla River at Milton-Freewater, OR annual flow volume ranking for water years 1970-2016.

Ranking	Water Year	Annual Flow Volume (Acre-feet)
1	1974	140,070
2	1996	125,402
3	1997	122,850
4	2011	120,931
5	1976	115,770
6	1972	114,465
7	2009	112,648
8	1982	108,745
9	1971	108,465
10	1975	106,875
11	1984	105,262
12	2000	96,317
13	1983	95,593
14	1995	93,607
15	1970	93,268
16	2012	92,770
17	2013	92,563
18	1999	92,440
19	2008	91,042
20	2014	90,206
21	2004	89,675
22	1978	87,830
23	1985	87,533
24	1981	86,542
25	1986	86,286
26	1993	85,422
27	1979	84,504
28	2006	83,857
29	2002	83,005
30	2003	82,897
31	2007	82,467
32	1998	81,422
33	2001	79,349
34	1989	79,101
35	2010	76,077
36	2016	75,479
37	1980	75,043
38	1991	74,137
39	2015	72,896
40	1990	70,994
41	1973	67,560
42	1994	67,331
43	1987	64,677
44	1977	62,672
45	1992	62,660
46	2005	60,206
47	1988	55,670

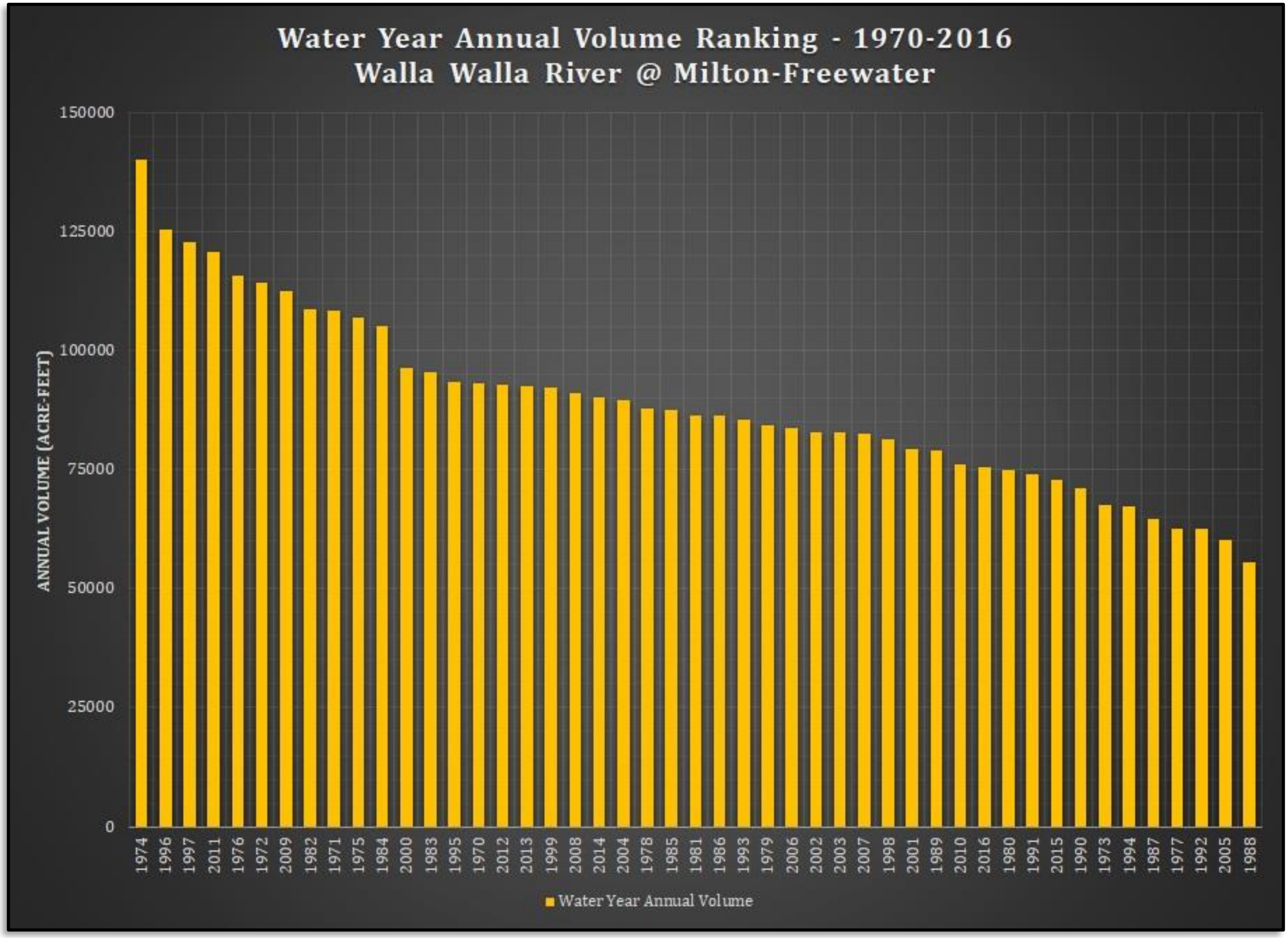


Figure 6 - Histogram of Walla Walla River at Milton-Freewater annual volumes (in acre-feet), ranked from highest volume to lowest volume, water years 1970-2016.

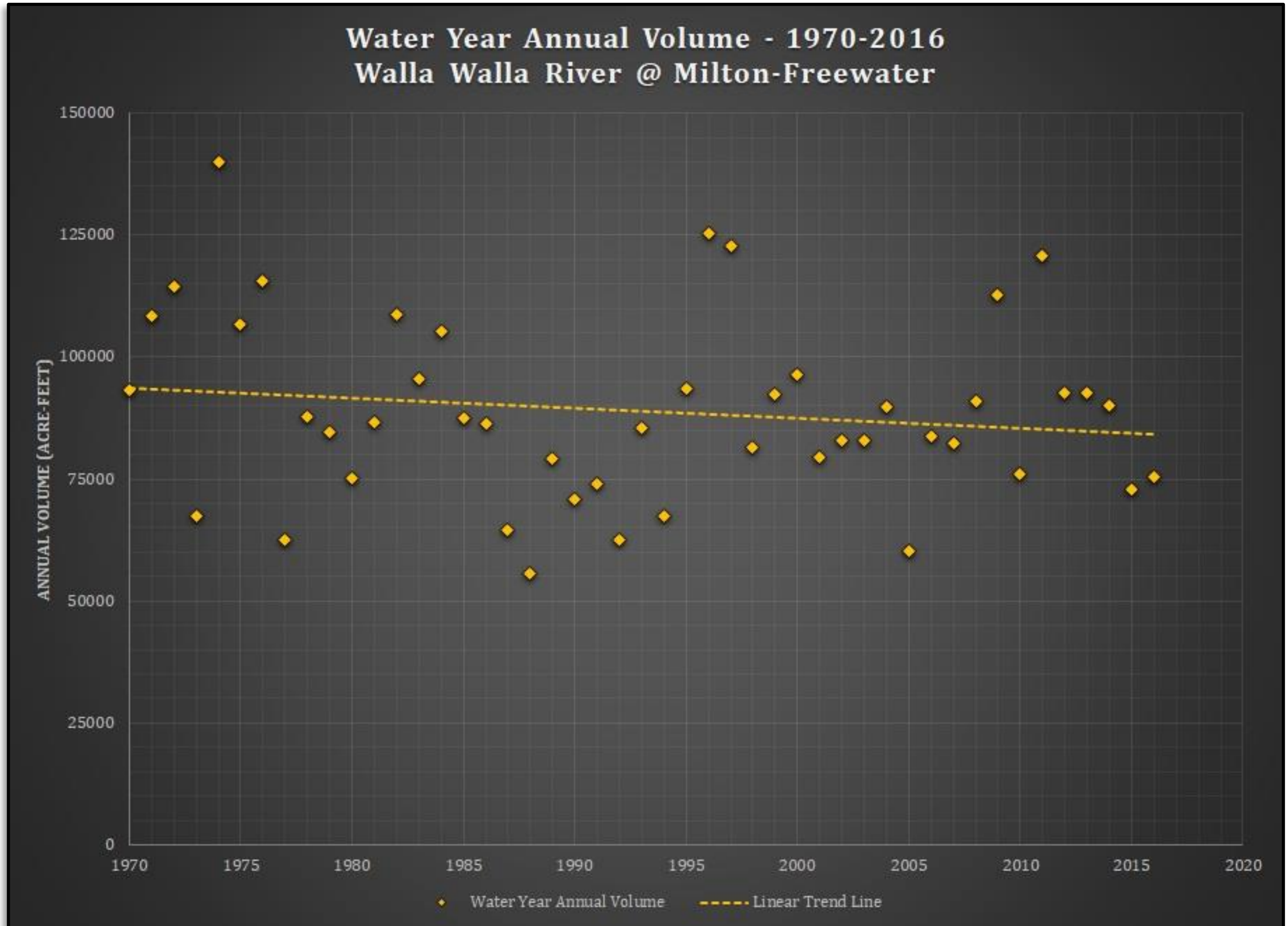


Figure 7 – Scatter plot of Walla Walla River at Milton-Freewater annual volumes (in acre-feet) for water years 1970-2016. Yellow dashed line in a linear trend line of the data.

Table 7 – Pine Creek annual flow volume ranking for water years 1970-2016.

Ranking	Water Year	Annual Flow Volume (Acre-feet)
1	1997	23,600
2	1974	22,346
3	1996	19,633
4	1976	18,445
5	2011	16,119
6	2009	15,403
7	1972	15,138
8	1975	14,450
9	1995	12,417
10	2012	11,916
11	2002	11,827
12	1982	11,816
13	1971	11,665
14	2014	11,614
15	2000	11,609
16	1999	11,351
17	2013	11,278
18	2003	11,104
19	1989	10,539
20	1970	10,404
21	2008	10,350
22	2004	10,278
23	1979	9,949
24	1984	9,917
25	2006	9,775
26	1978	9,636
27	2016	9,581
28	1983	9,048
29	1981	8,932
30	2007	8,635
31	1993	8,609
32	1986	7,947
33	1985	7,840
34	1991	7,625
35	2010	7,089
36	1998	7,045
37	2015	6,939
38	1980	6,624
39	1990	6,480
40	1987	6,091
41	2001	5,560
42	1973	5,552
43	2005	5,026
44	1988	4,986
45	1992	4,691
46	1994	4,581
47	1977	3,755

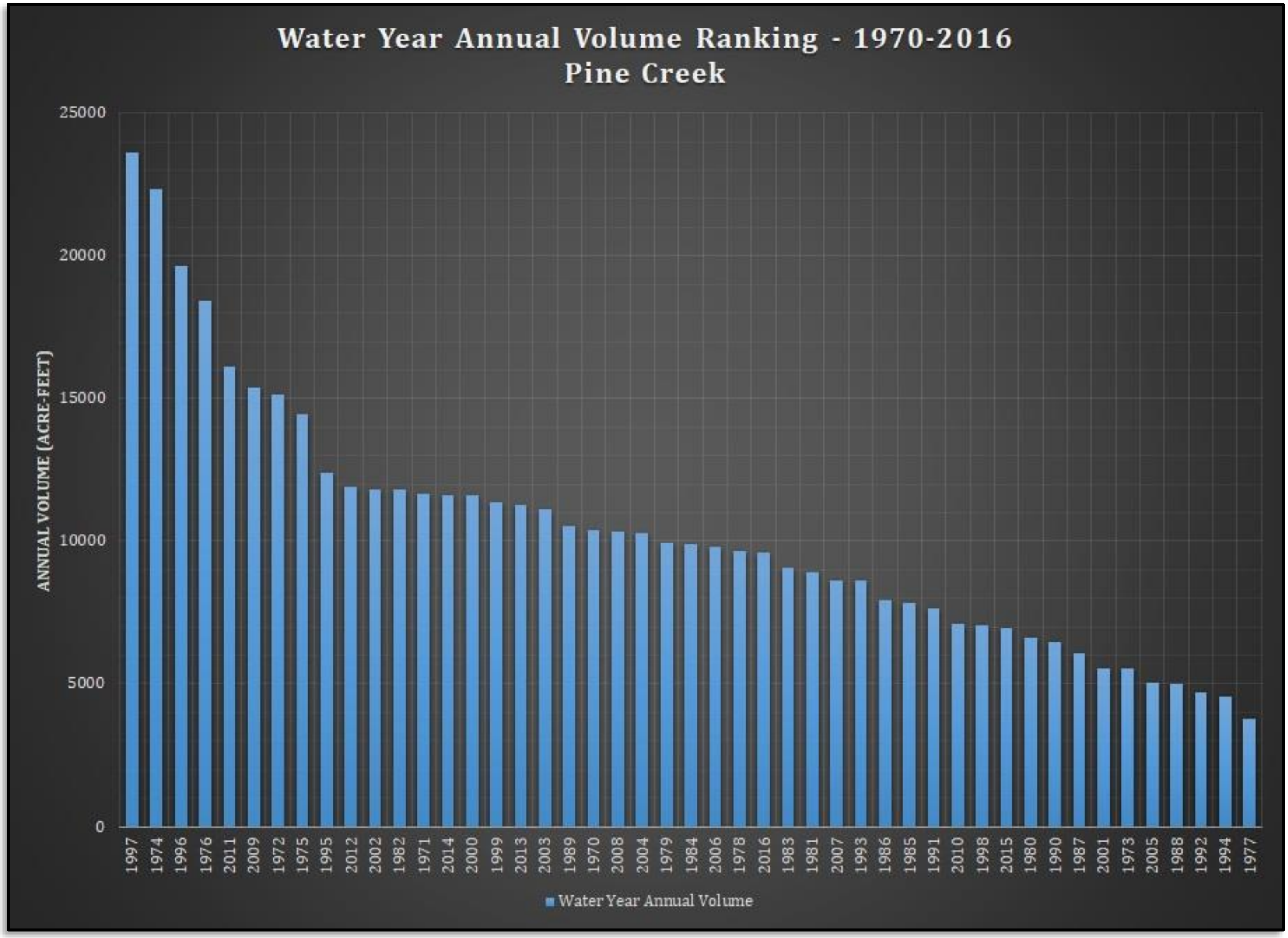


Figure 8 - Histogram of Pine Creek annual volumes (in acre-feet), ranked from highest volume to lowest volume, water years 1970-2016.

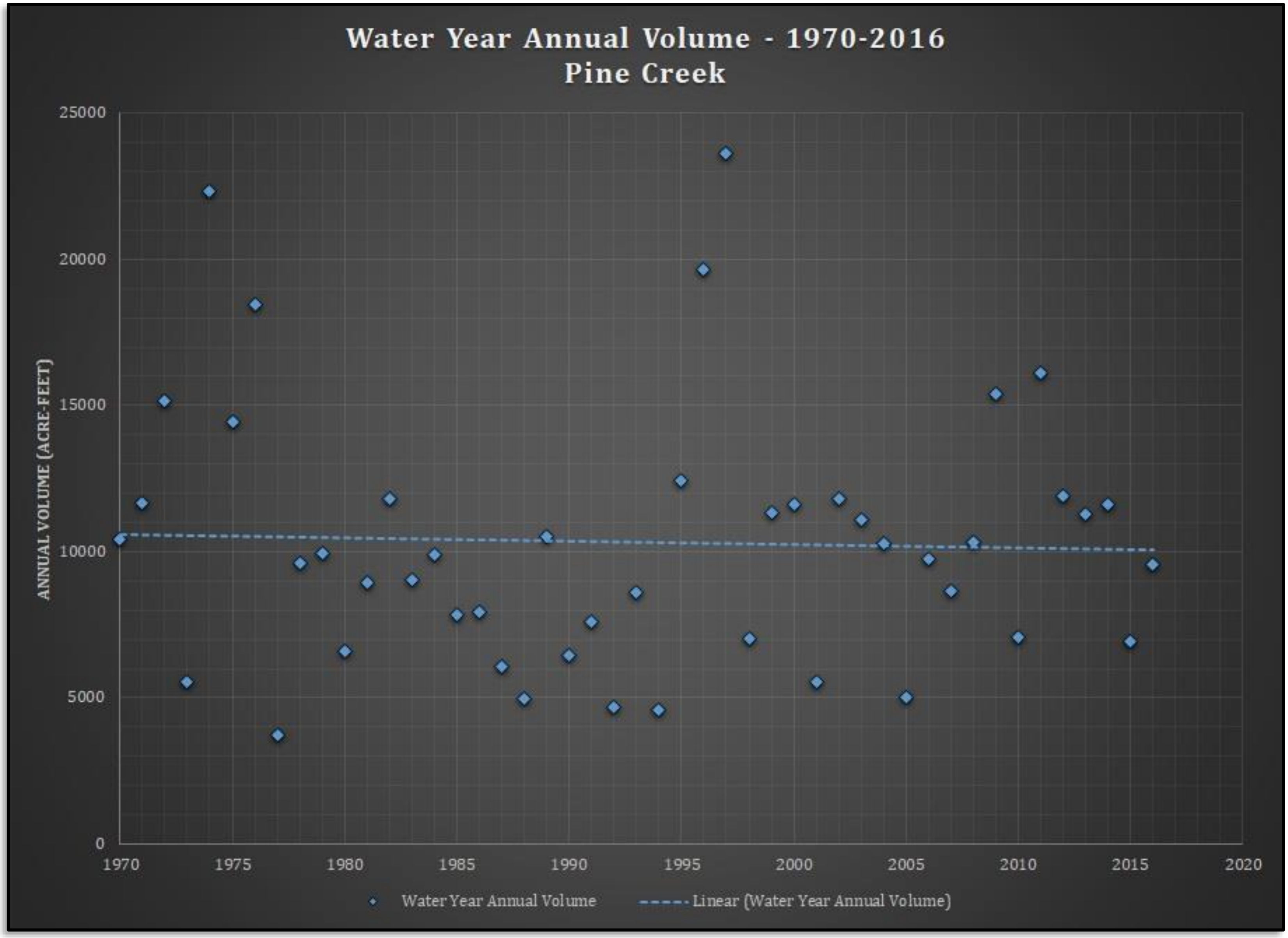


Figure 9 – Scatter plot of Pine Creek annual volumes (in acre-feet) for water years 1970-2016. Blue dashed line in a linear trend line of the data.

Walla Walla River at Milton-Freewater Annual Volume Exceedance

The annual volume values for the Walla Walla River at Milton-Freewater were analyzed to create a annual volume exceedance graph (Figure 10). Water year annual volumes were imported into R and "Flow Duration Curve" (FDC) function within the hydroTSM R package. The FDC function was modified from the default configuration to fit the annual volume exceedance requirements. This analysis is limited by the "short" period of record – 47 years. Therefore, exceedance values should be viewed/used with an understanding of the limited framework of the dataset.

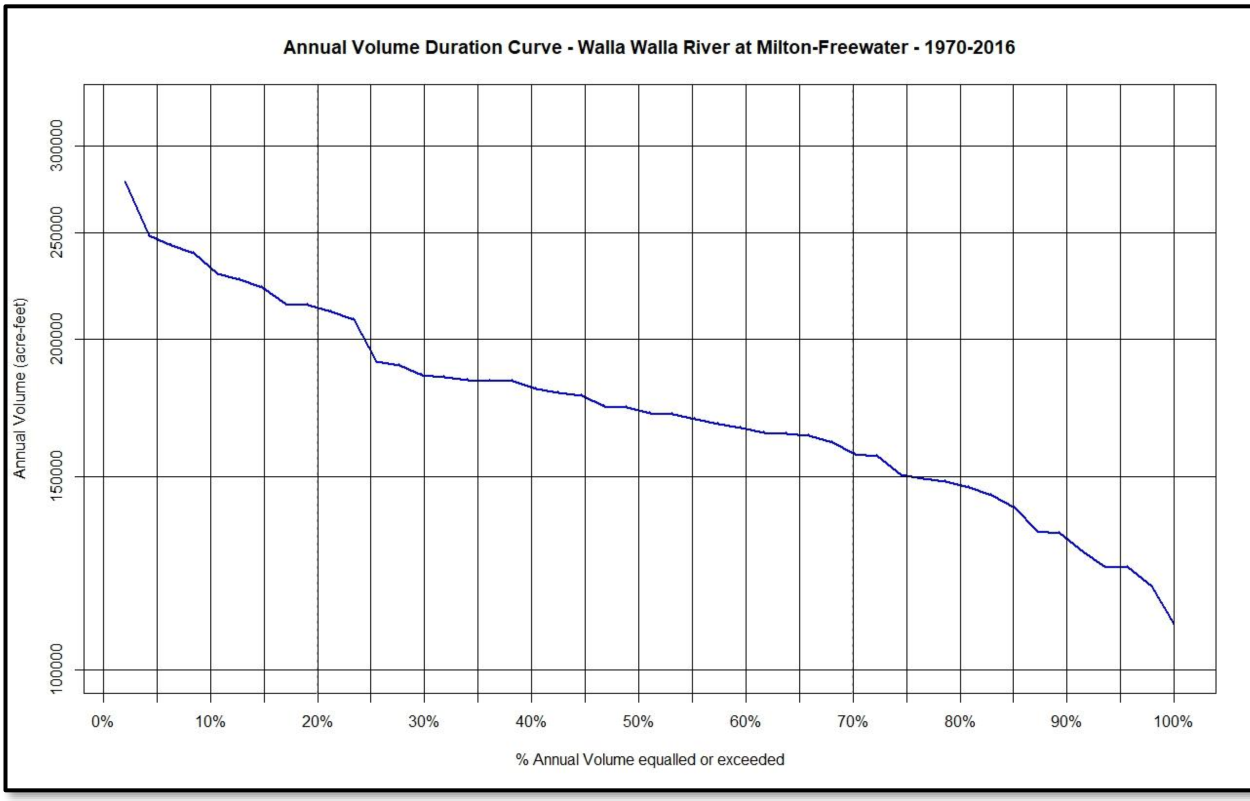


Figure 10 - Annual water volume exceedance graph for the Walla Walla River at Milton-Freewater for water years 1970-2016.

"Dry", "Normal" and "Wet" Average Hydrographs

Five year average datasets were created to represent "Dry" (75% exceedance), "Normal" (50% exceedance) and "Wet" (25% exceedance) conditions. Utilizing the water year ranking (see above), the five years bracketing each of the exceedances (i.e. 25%, 50% and 75%) were averaged to create a five year average flow for each condition. Each condition (Dry, Normal and Wet) was graphed compared to flow upstream of the Little Walla Walla River point of diversion (POD) at Cemetery Bridge in Milton-Freewater, river mile 45.9, historic flow downstream of the POD, 20% diversion for reservoir storage and 30% diversion for reservoir storage (Figures 11-13).

In addition, five year delta average datasets were created and graphed (Figures 14-16). The delta average datasets for both 20% and 30% diversion indicate when diversions occur (negative values – typically during winter and spring) and when stored reservoir water is utilized to improve instream flows via water rights exchange or direct return to the Walla Walla River (positive values – typically during late spring, summer and fall).

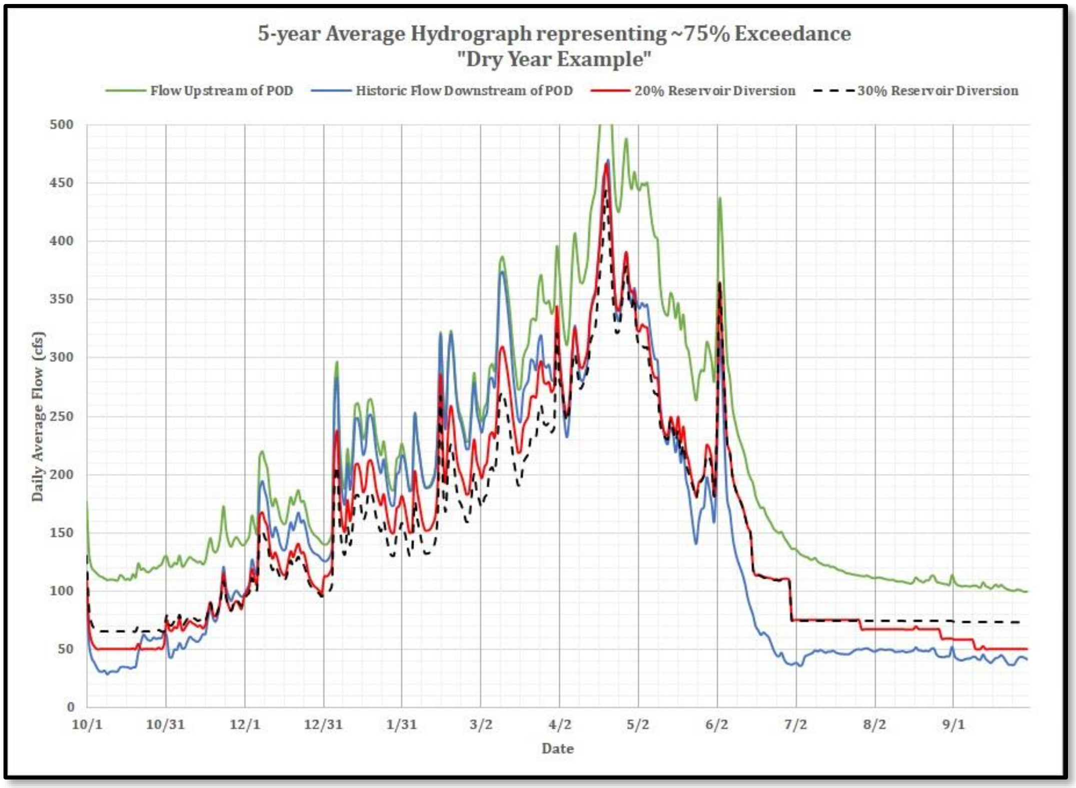


Figure 11 - Hydrograph of the 5-year average representing "Dry" conditions (75% exceedance) under potential reservoir diversion scenarios.

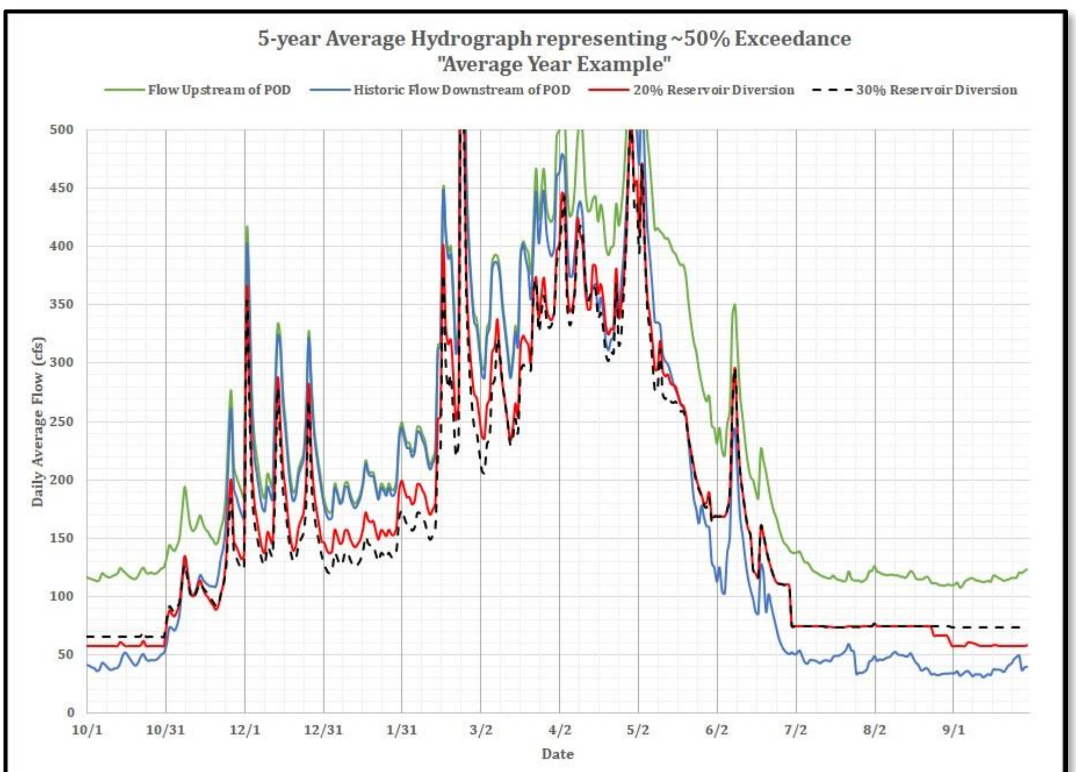


Figure 12 - - Hydrograph of the 5-year average representing "Normal" conditions (50% exceedance) under potential reservoir diversion scenarios.

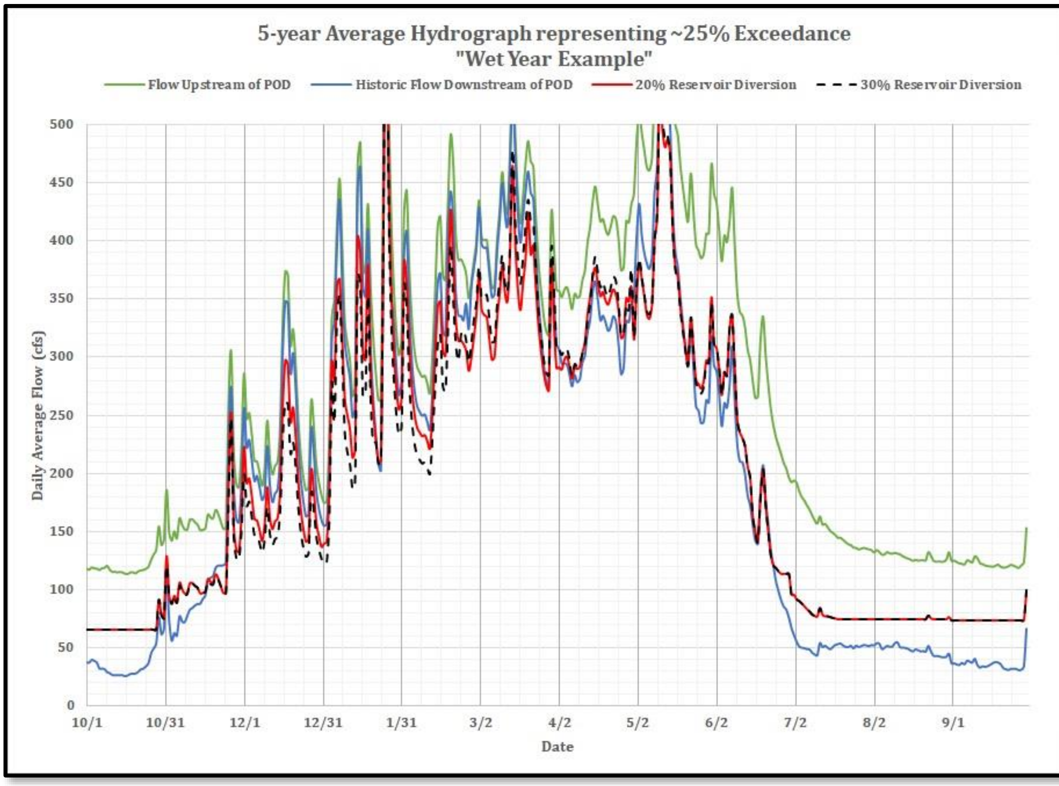


Figure 13 - Hydrograph of the 5-year average representing "Wet" conditions (25% exceedance) under potential reservoir diversion scenarios.

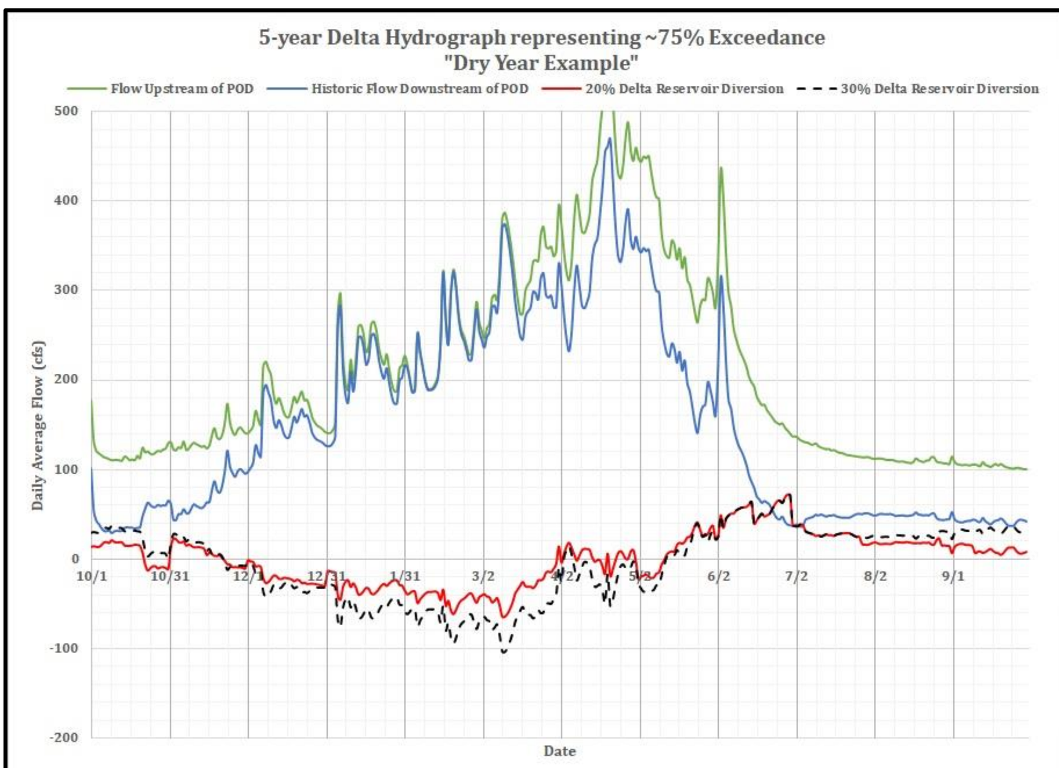


Figure 14 - Hydrograph of the 5-year average representing delta "Dry" conditions (75% exceedance) under potential reservoir diversion scenarios.

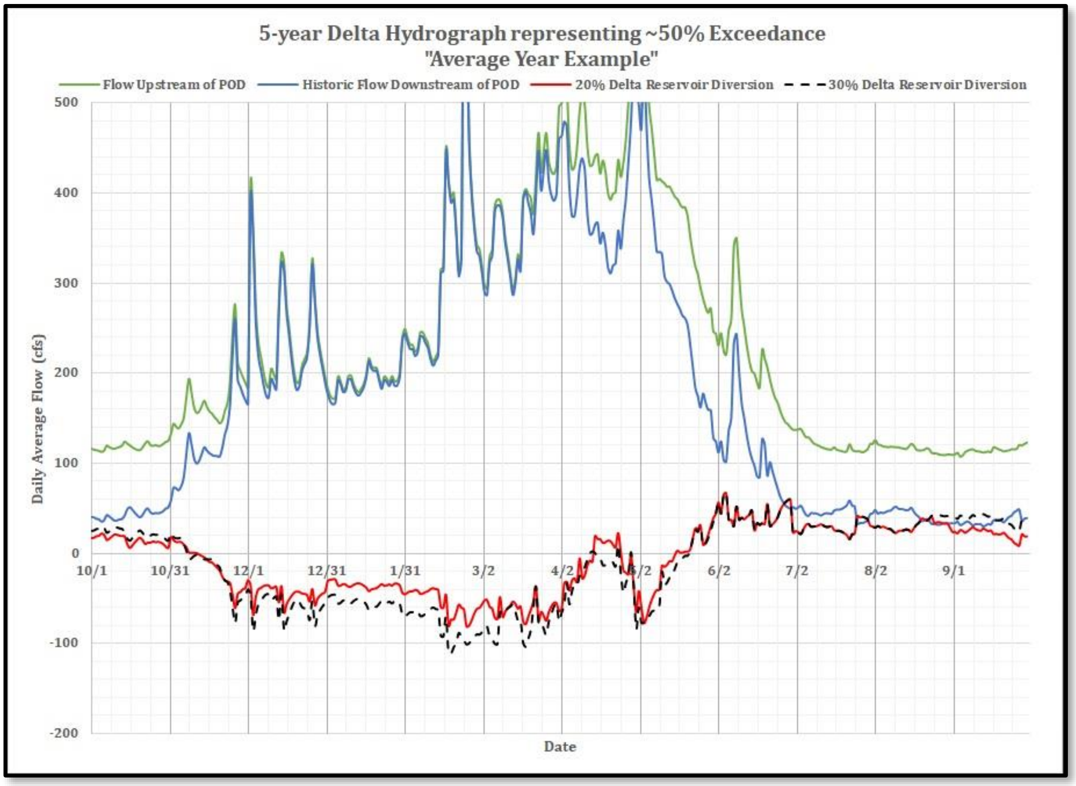


Figure 15 - Hydrograph of the 5-year average representing delta "Normal" conditions (50% exceedance) under potential reservoir diversion scenarios.

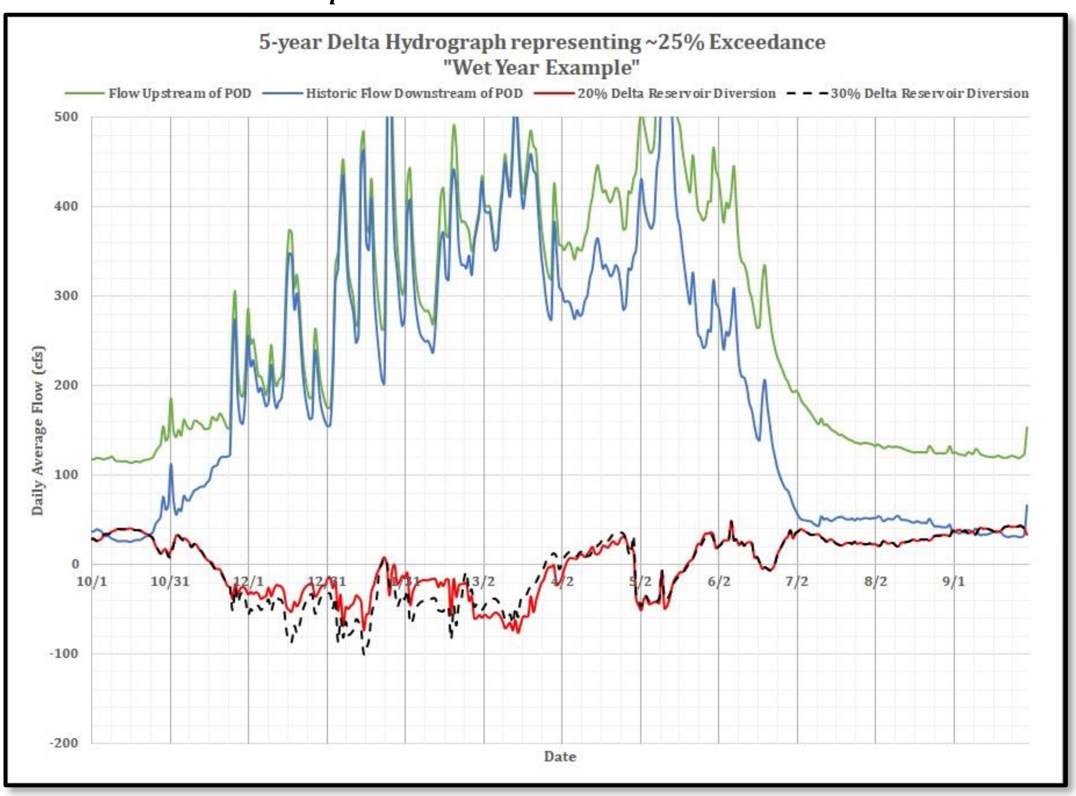


Figure 16 - Hydrograph of the 5-year average representing delta "Wet" conditions (25% exceedance) under potential reservoir diversion scenarios.

Walla Walla River Average Flow

Daily average flow values for the period of record (1970-2016) were averaged to create an average flow dataset for the Walla Walla River at Milton-Freewater (Figure 17). Average values were calculated from the Walla Walla River Composite Dataset (see above).

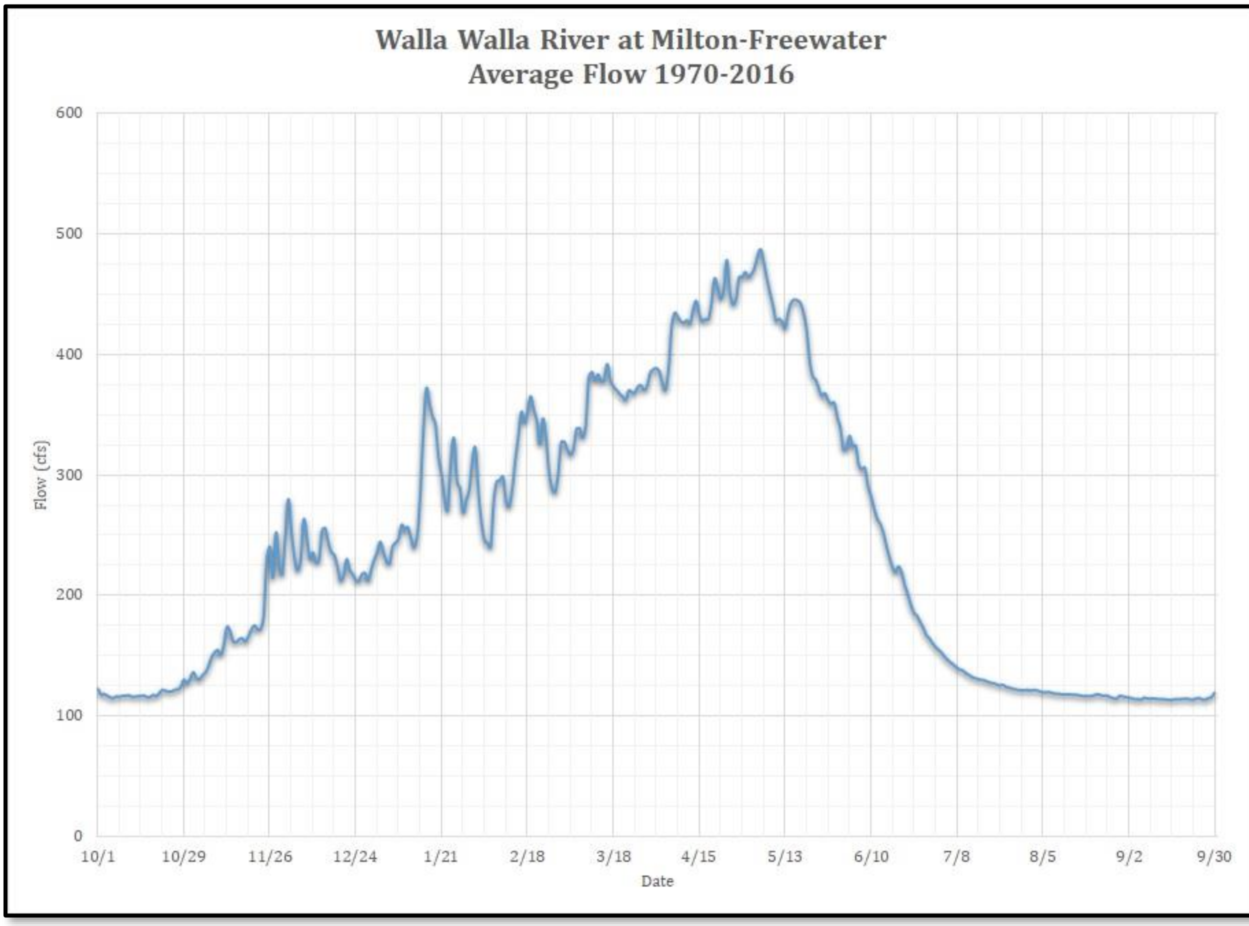


Figure 17 - Hydrograph of average flow for the Walla Walla River at Milton-Freewater for the period of record of water years 1970-2016.

Flood Frequency Analysis

An analysis of flood frequencies was performed on the derived "Walla Walla River Composite" (also known as "Flow Upstream of POD"), "Downstream Historic", "20% Reservoir Diversion" and "30% Reservoir Diversion" datasets. Daily average flow for each dataset was imported into AQUARIUS Time-series (www.aquaticinformatics.com). It should be noted, this analysis differs from most other flood discharge analyzes completed in the past (e.g. Corps 2007, GeoEngineers 2011, and others) including a limited data range (WY 1970-2016), different reach of interest, using daily average flow data ("Walla Walla River Composite"), presenting daily average flow results (instead of instantaneous flow) and other variables. The primary purpose of this analysis was to determine the potential impact of reservoir diversions on frequent (2-10 years) flood flow intensity and, therefore, should not be used for other purposes. Each dataset was analyzed using AQUARIUS's "Hydrologic Statistics" toolbox (Figure 18). An annual population set was generated from maxima for each year using the California method (P=rank/n) and plotted (Figure 19). A cumulative distribution function chart was created for each population. All common distribution types (e.g. Pearson Type III, Log Pearson, etc) were plotted on the same chart for comparison (Figure 20). Parameters for each distribution type were estimated using AQUARIUS's built in "L-Moments estimator" tool and distribution parameters are included in the data files. Tests for general randomness, independence and trend were conducted (see Figures 21-23). Return periods of 2, 5, 10, 15, 20, 25, 50, 100, 200 and 500 years were analyzed for each dataset. Return values above 25-50 years are likely inaccurate due to a short period of record and the underlying dataset. Flow values are provided for each of the formula types in the cumulative distribution function chart. A summary of each dataset is included in Appendix C.

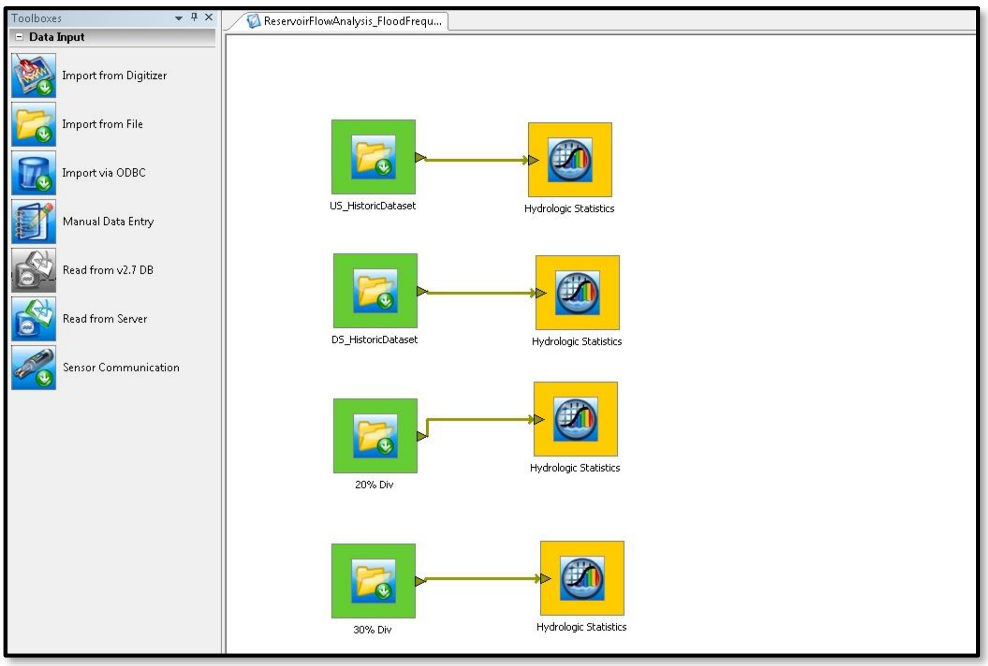


Figure 18 - Screenshot of AQUARIUS Whiteboard with datasets imported and analyzed with the "Hydrologic Statistics" toolbox.

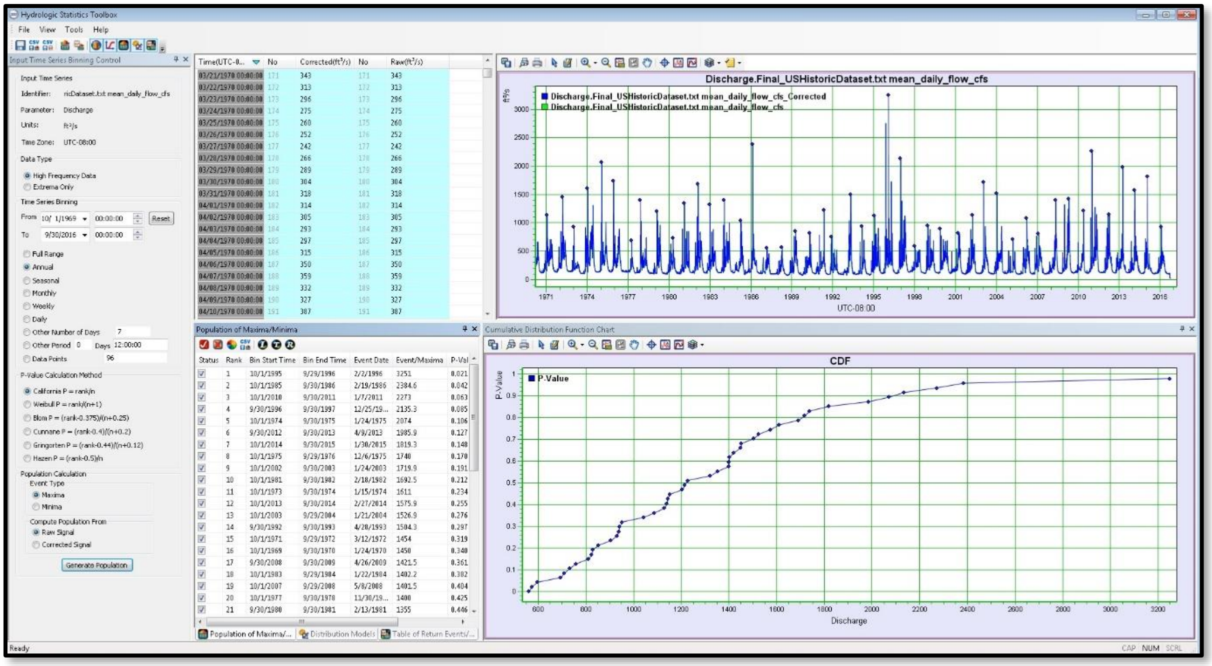


Figure 19 - Screenshot of AQUARIUS Hydrologic Statistics toolbox with annual maxima population generated using the California method (P=rank/n).

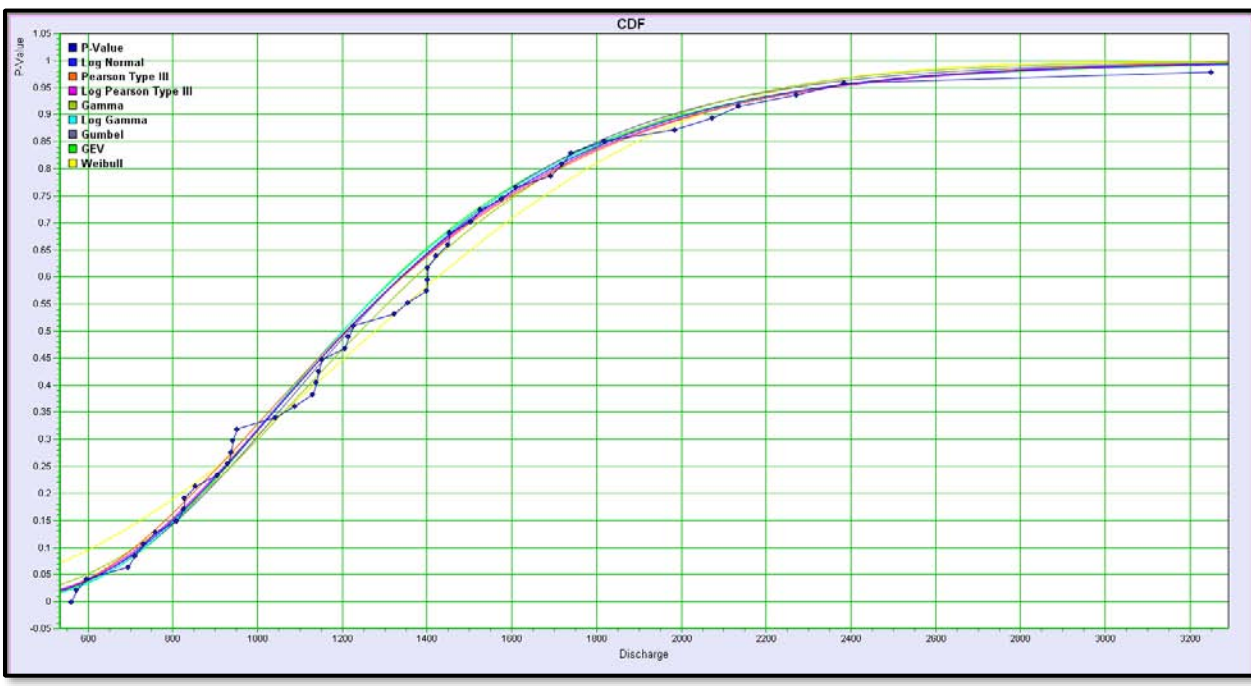


Figure 20 - Cumulative distribution function chart for "Upstream of POD" dataset. Various formula are included for comparison.

Run Test for General Randomness

Discharge.Final_USHistoricDataset.txt mean_daily_flow_cfs

The number of runs above and below the median = 25
The number of observations above the median(n1) = 23
The number of observations below the median(n2) = 23

(Note: Z is the standard normal variate.)

For this test, Z = 0.298216
Critical Z value at the 5% level = 1.960 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

Figure 21 - Screenshot of results of the test for general randomness (built in AQUARIUS).

Spearman Test for Independence

Discharge.Final_USHistoricDataset.txt mean_daily_flow_cfs

Spearman Rank Order Serial Correlation Coeff = 0.0593895
Corresponds to Students T = 0.394642
Critical T Value at 5% Level = 1.673 NOT SIGNIFICANT
Critical T Value at 1% Level = 2.395 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

Figure 22 - Screenshot of results of the Spearman test for independence (built in AQUARIUS).

Spearman Test for Trend

Discharge.Final_USHistoricDataset.txt mean_daily_flow_cfs

Spearman Rank Order Serial Correlation Coeff = -0.0401249
Corresponds to Students T = -0.269383
Critical T Value at 5% Level = -1.673 NOT SIGNIFICANT
Critical T Value at 1% Level = -2.395 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

Figure 23 - Screenshot of results of the Spearman test for trend (built in AQUARIUS).

Annual Water Volumes Examination

An initial examination of total water volumes was conducted at three gauge locations in the Walla Walla Basin: S-105 Walla Walla River @ Milton-Freewater, S-108 Walla Walla River @ Pepper Bridge and S-609 Touchet River at Cummins Road. Daily average flow data was compiled and converted into daily volume (acre-feet). Daily acre-feet values were added on a daily time-step to create total acre-feet hydrographs for each location (Figures 24-29). In addition, available daily acre-feet values were adjusted to account for instream flow requirements. If instream flows were not being met, no water was deemed available. Instream flow requirements were established based on the adopted instream flow targets for the WWR @ Milton-Freewater and Pepper Bridge (100 cfs from July 1 – Nov 30 and 150 cfs from Dec 1 – June 30 – note these values have been adjusted since this analysis was completed – see Table 1) and on Washington Administrative Code (WAC) 173-532 for the Touchet River @ Cummins Road (Instream flows were taken from MP 11 – Toucher River @ Bolles – see Table 8). If a month was closed due to WAC 173-532 (i.e. May-November), there was assumed to be no available water during that month in this analysis.

The Walla Walla River at Milton-Freewater produced between 127,000 and 242,000 acre-feet for the years 2007-2015 (Figure 24). When proposed instream flow targets are applied, potential available water ranges from approximately 36,000 to 150,000 acre-feet per year (Figure 25). This volume of water is not what would/could be permitted, but rather gives an approximation of the potential magnitude of unallocated/unused water at this gauge location. For the Walla Walla River at Pepper Bridge, the annual water volume ranges from 63,000 to 182,000 acre-feet (Figure 26). The difference between the Milton-Freewater and Pepper Bridge gauges is likely a rough estimate of annual diversion for irrigation and other out-of-stream uses. When proposed instream flow targets are applied, potential available water ranges from approximately 13,000 to 108,000 acre-feet per year (Figure 27). This volume of water is not what would/could be permitted, but rather gives an approximation of the potential magnitude of unallocated/unused water at this gauge location. The Touchet River at Cummins Road varies from 60,000 to 239,000 acre-feet a year in annual water volume (Figure 28). When WAC 173-532 instream flows are considered, potential annual water volumes are approximately 8,000 to 132,000 acre-feet per year (Figure 29). This volume of water is not what would/could be permitted, but rather gives an approximation of the potential magnitude of unallocated/unused water at this gauge location.

Table 8. Instream flows for the Touchet River based on WAC 173-532.

Month	Instream Flows – Touchet River at Bolles (MP 11)	Instream Flows – Touchet River at Cummins Road
January	150	150
February	150	150
March	200	200
April	200	200
May	200 (Closure)	200 (Closure)
June	125 (Closure)	125 (Closure)
July	74 (Closure)	74 (Closure)
August	48 (Closure)	48 (Closure)
September	56 (Closure)	56 (Closure)
October	82 (Closure)	82(Closure)
November	150 (Closure)	150 (Closure)
December	150	150

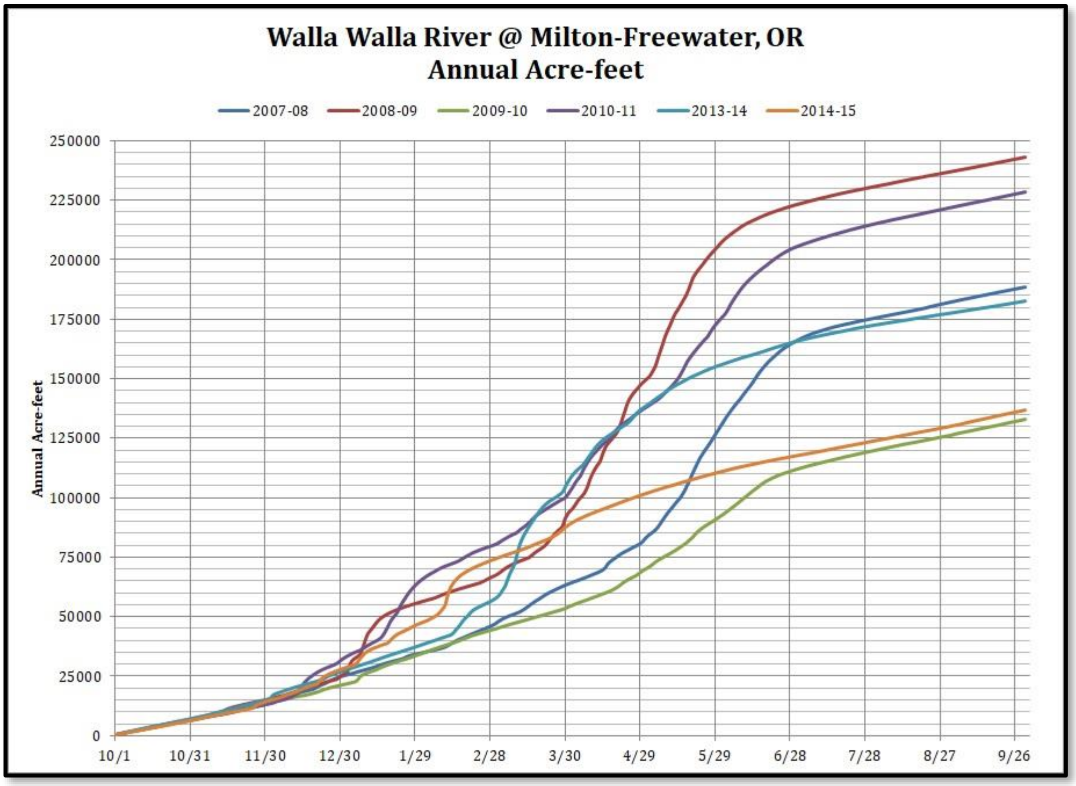


Figure 24 - Annual water volume (acre-feet) for years 2007-2015 for the Walla Walla River at Milton-Freewater.

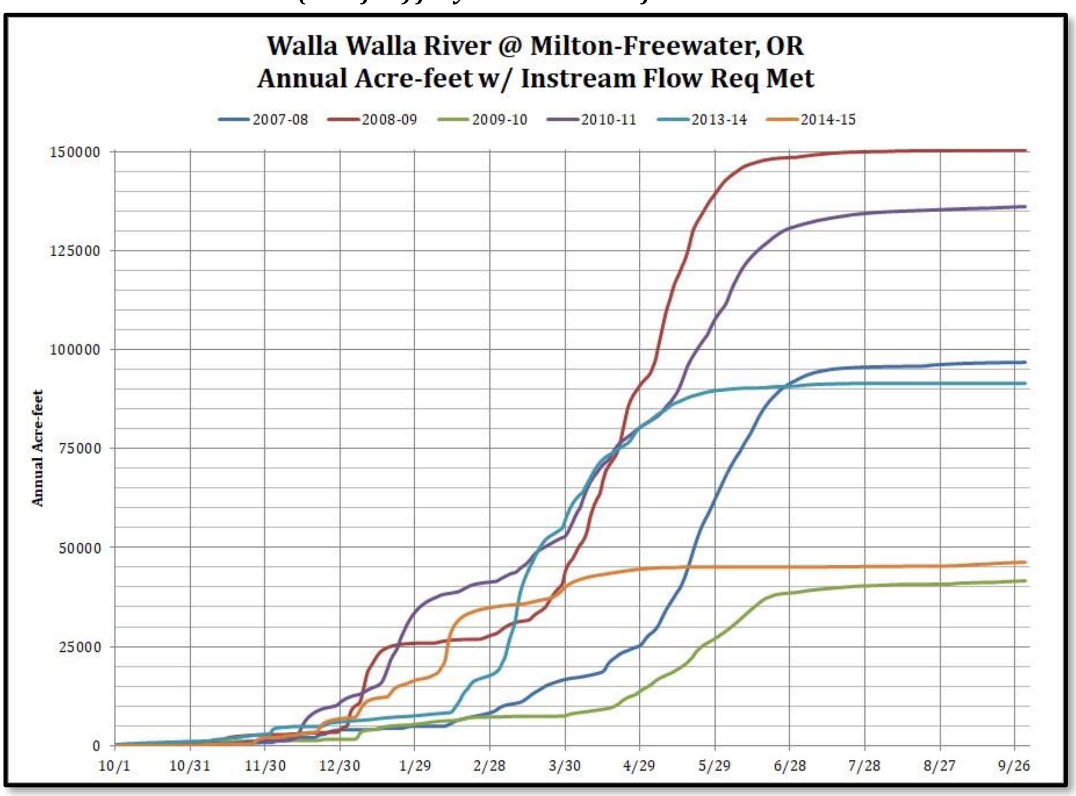


Figure 25 - Annual water volume (acre-feet) after subtracting proposed instream flow targets for years 2007-2015 for the Walla Walla River at Milton-Freewater.

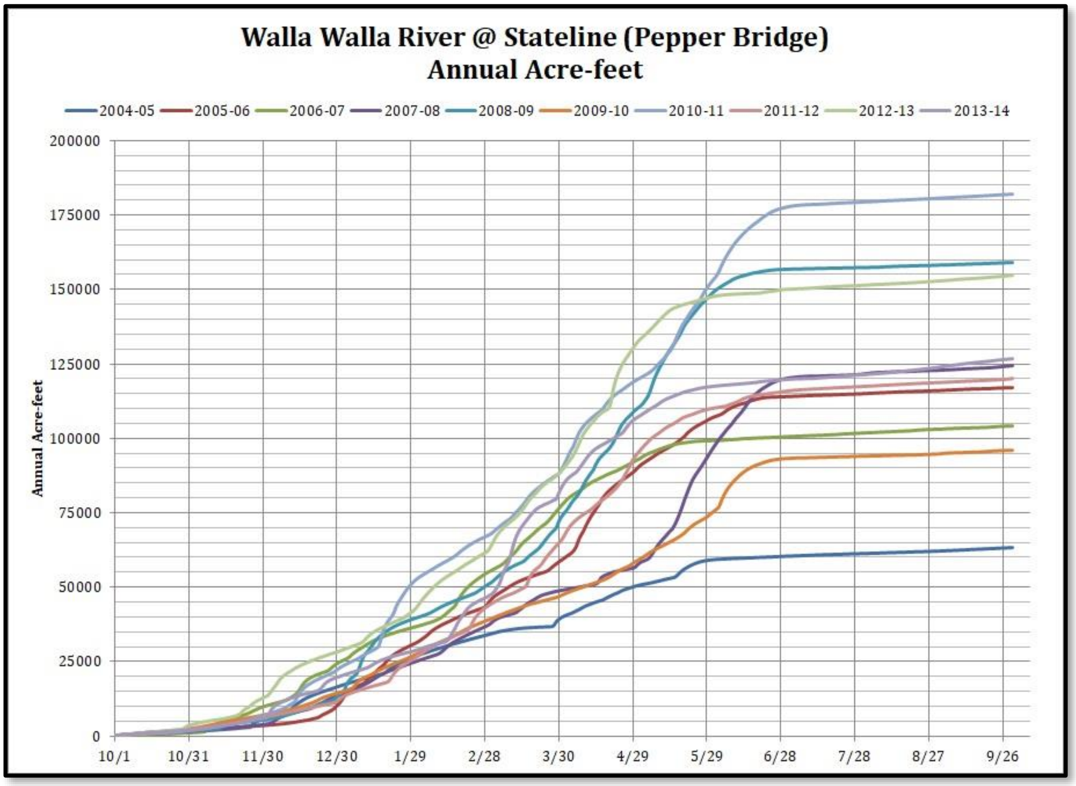


Figure 26 - Annual water volume (acre-feet) for years 2004-2014 for the Walla Walla River at Pepper Bridge.

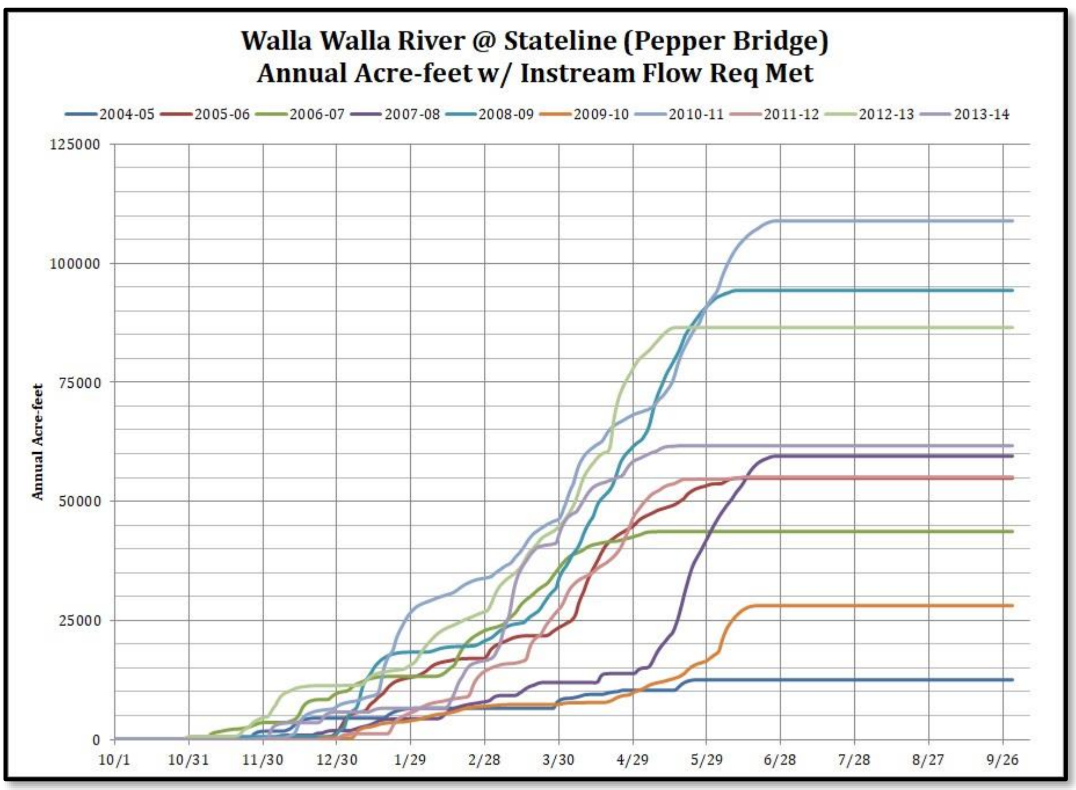


Figure 27 - Annual water volume (acre-feet) after subtracting proposed instream flow targets for years 2004-2014 for the Walla Walla River at Pepper Bridge.

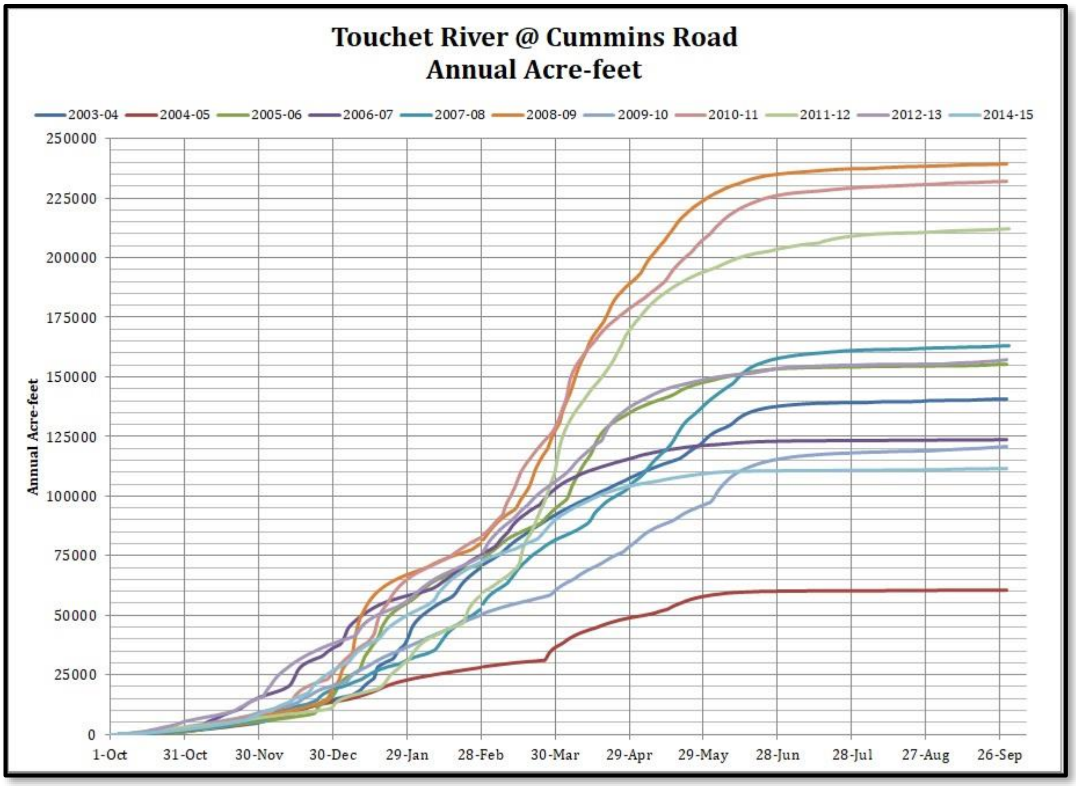


Figure 28 - Annual water volume (acre-feet) for years 2003-2015 for the Touchet River at Cummins Road.

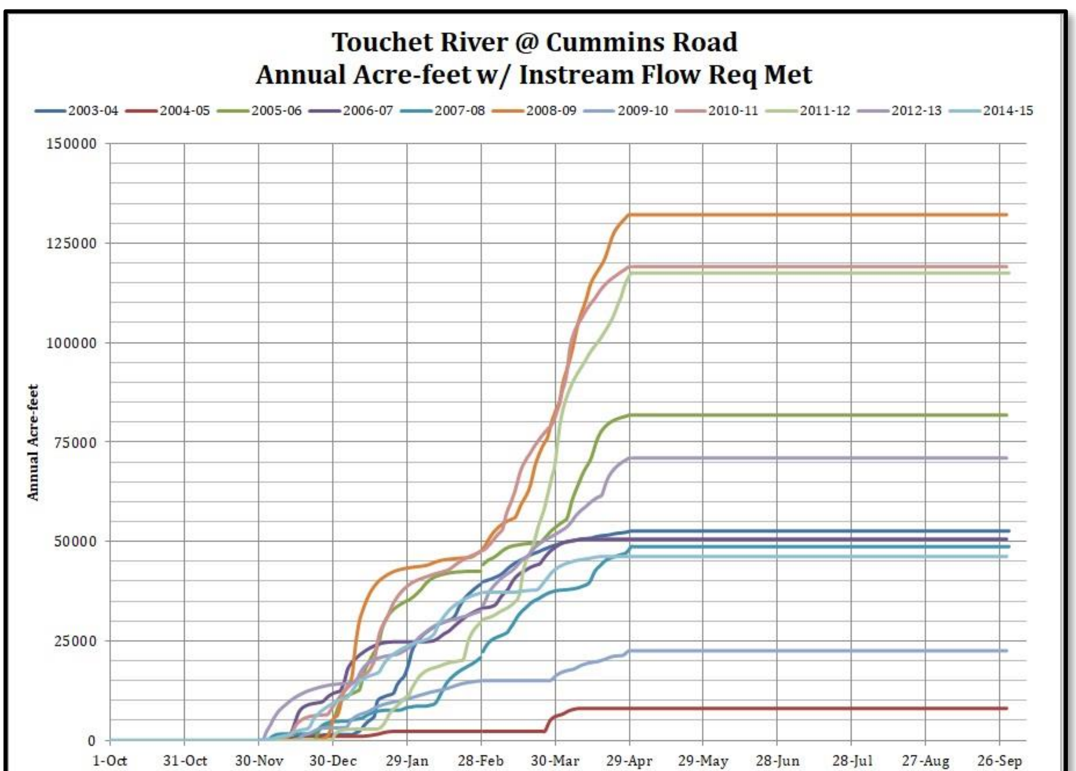


Figure 29 - Annual water volume (acre-feet) after subtracting proposed instream flow targets for years 2003-2015 for the Touchet River at Cummins Road.

Managed Aquifer Recharge Instream Flow Contributions

Instream flow benefits from active aquifer recharge sites was analyzed using the Walla Walla Basin Integrated Water Flow Model. In support of the Walla Walla Basin Integrated Flow Enhancement Study, GeoSystems Analysis, Inc. applied the calibrated surface water - groundwater numerical finite element model for the Walla Walla Basin to evaluate the potential impacts of proposed water management scenarios on hydrological conditions in the basin. The basin model utilizes the Integrated Water Flow Model (IWFM), developed by the California Department of Water Resources Bay-Delta Office (www.baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM). Results for two scenarios, No Managed Aquifer Recharge (No MAR) and Current Managed Aquifer Recharge (Current MAR), were compared (Figures 30 & 31). The only difference in these scenarios is the operation of managed aquifer recharge sites therefore any instream flow change can be attributed to managed aquifer recharge operations. The entire report is available on the WWBWC website: http://wwbwc.org/projects/modeling.html

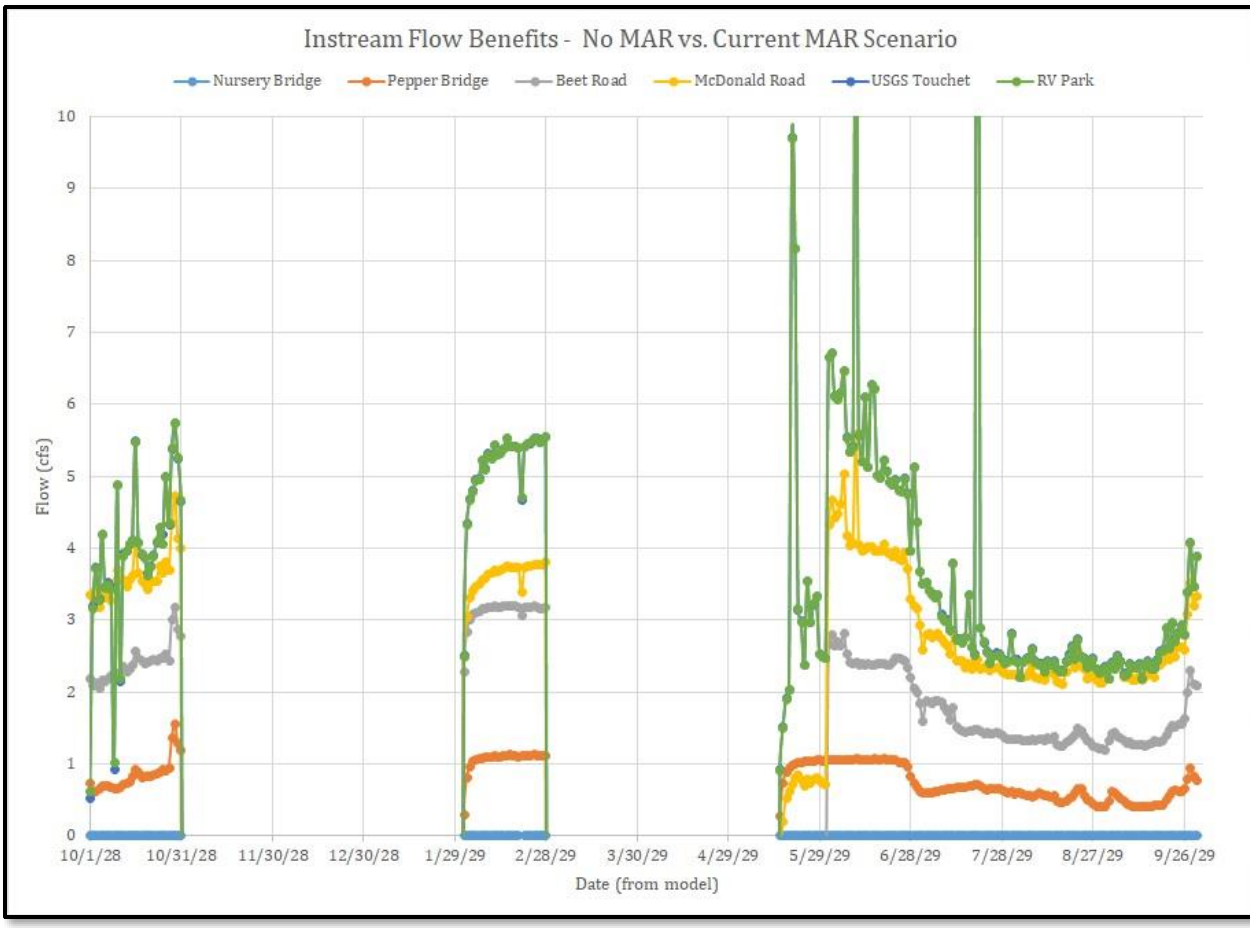


Figure 30 - Instream flow benefits from Current MAR sites at various stream gauge locations on the Walla Walla River. Results are derived from the Walla Walla Basin IWFM model.

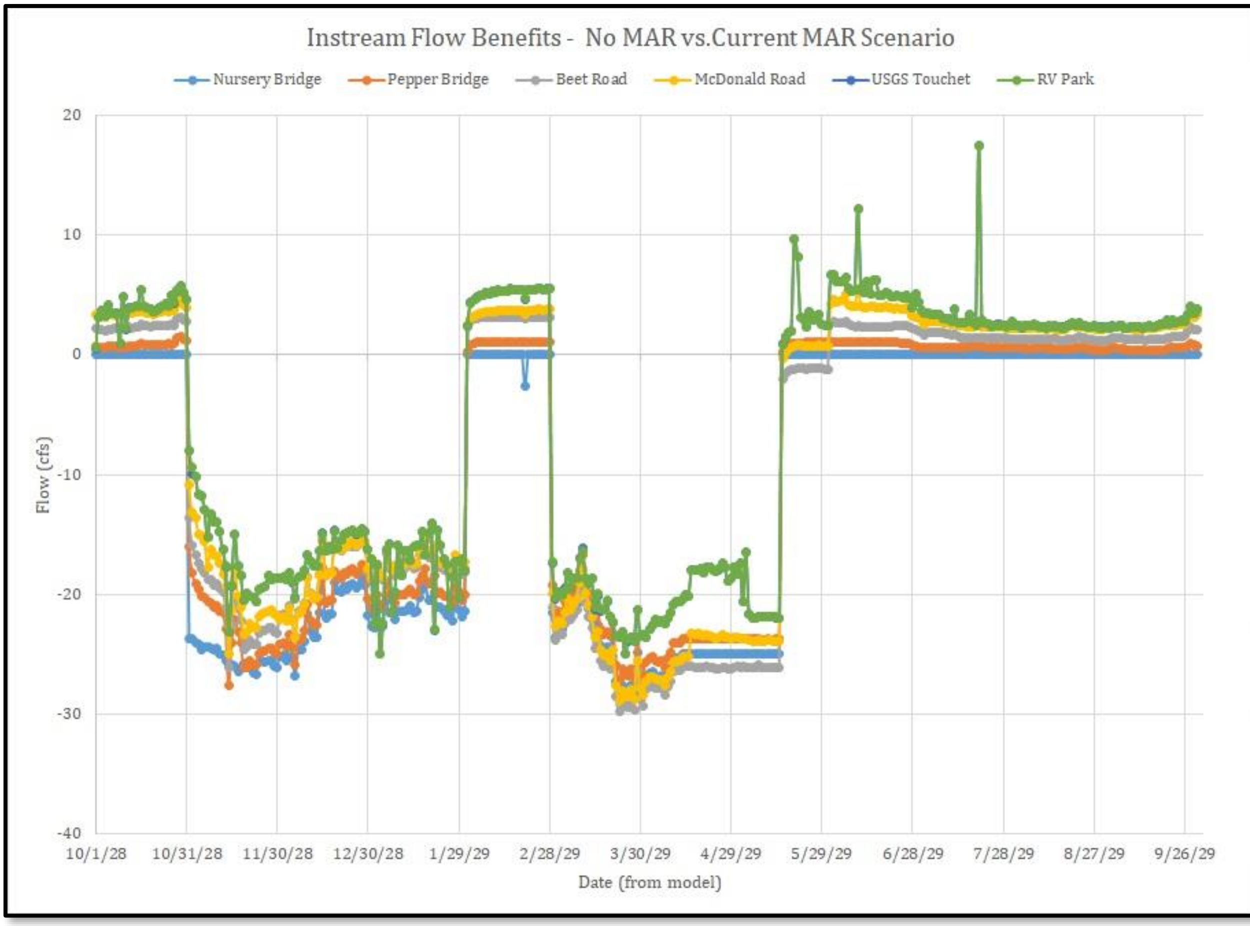


Figure 31 - Instream flow impacts from Current MAR scenarios. Positive values indicate instream flow improvements and negative values indicate MAR diversions during winter/spring periods.

Appendix A – R Code and files

Current Instream Flow Analysis – Example is S105 (code for other sites is the same except for site number and input file names)

OCR_FlowAnalysis_S105.R

Steven

Mon Jul 31 16:37:24 2017

++

Flow Analysis for OCR WWBIFES

Prepared by Steven Patten, Walla Walla Basin Watershed Council steven.patten@wwbwc.org

January 2017

copyright 2017

++ INPUT DATA

load data for management location

```
inFile <- "S105_MeanMedian_Daily.txt"
```

Data are read using read.delim. na.strings and comment.char arguments are changes from the default. na.strings has Bkw added for some measurememnts that have that value if that is not included the field is loaded as factor requiring casting backflips to get it to numeric values. comment.char has a default value of "". The header of the data file has lines beginning with #'. Setting comment.char to #' tells R to skip those lines

```
s105Data <- read.delim(inFile, na.strings = c("NA", "Bkw"),
                        comment.char = "#")
```

Rename Columns - The order is the same as in the data file.

```
columnNames <- c("Date", "SiteName", "Agency",
                 "MeanDischarge", "MedianDischarge",
                 "BiMonth")
```

Change the column names to better values

```
names(s105Data) <- columnNames
```

Take a look at the data

```
head(s105Data)

##             Date SiteName Agency MeanDischarge MedianDischarge BiMonth
## 1 7/17/2002 0:00     S105  WWBWC      111.3163              NA     7.5
## 2 7/18/2002 0:00     S105  WWBWC      110.9842              NA     7.5
## 3 7/19/2002 0:00     S105  WWBWC      107.5567              NA     7.5
## 4 7/20/2002 0:00     S105  WWBWC      106.3937              NA     7.5
## 5 7/21/2002 0:00     S105  WWBWC      105.7015              NA     7.5
## 6 7/22/2002 0:00     S105  WWBWC      107.8320              NA     7.5
```

+++++++DESCRIPTIVE STATISTICS+++

Descriptive statistics and histogram, create with minimum, maximum and range stats

```
min(s105Data$MeanDischarge)

## [1] NA

max(s105Data$MeanDischarge)

## [1] NA

range(s105Data$MeanDischarge)

## [1] NA NA
```

If stats return NA values, check for NA

```
any(is.na(s105Data$MeanDischarge))

## [1] TRUE
```

Determine number of NAs

```
length(which(is.na(s105Data$MeanDischarge)))

## [1] 2172
```

Summary statistic functions have a na.rm argument to determine whether NA values should be used in calculations. Set na.rm = T to exclude the values

```
min(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 74.83678

max(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 2154.323

range(s105Data$MeanDischarge, na.rm = TRUE)

## [1]   74.83678 2154.32281
```

Mean, variance, and sd

```
mean(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 234.2694

var(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 48282.81

sd(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 219.7335
```

Median and quartiles

```
mean(s105Data$MeanDischarge, na.rm = TRUE)

## [1] 234.2694

quantile(s105Data$MeanDischarge, na.rm = TRUE)

##          0%         25%         50%         75%        100%
##   74.83678  108.09271  144.99050  281.84032 2154.32281
```

The quantile has the probs argument to set the percentiles For the 10th and 90th percentiles set probs as

```
quantile(s105Data$MeanDischarge, probs = c(0.1,0.25,0.5,0.75, 0.9), na.rm = T
)

##       10%       25%       50%       75%       90%
##  98.23741 108.09271 144.99050 281.84032 465.63975
```

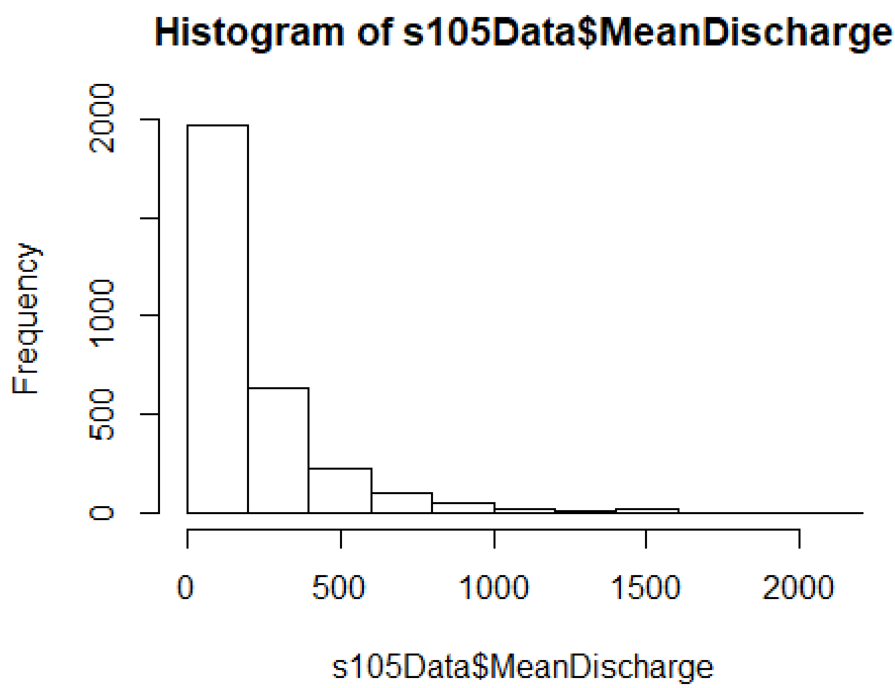
and summary which brings together mean, median, and quantiles no na.rm here. Summary counts the number of NAs in the data set.

```
summary(s105Data$MeanDischarge)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
##   74.84  108.10  145.00  234.30  281.80 2154.00    2172
```

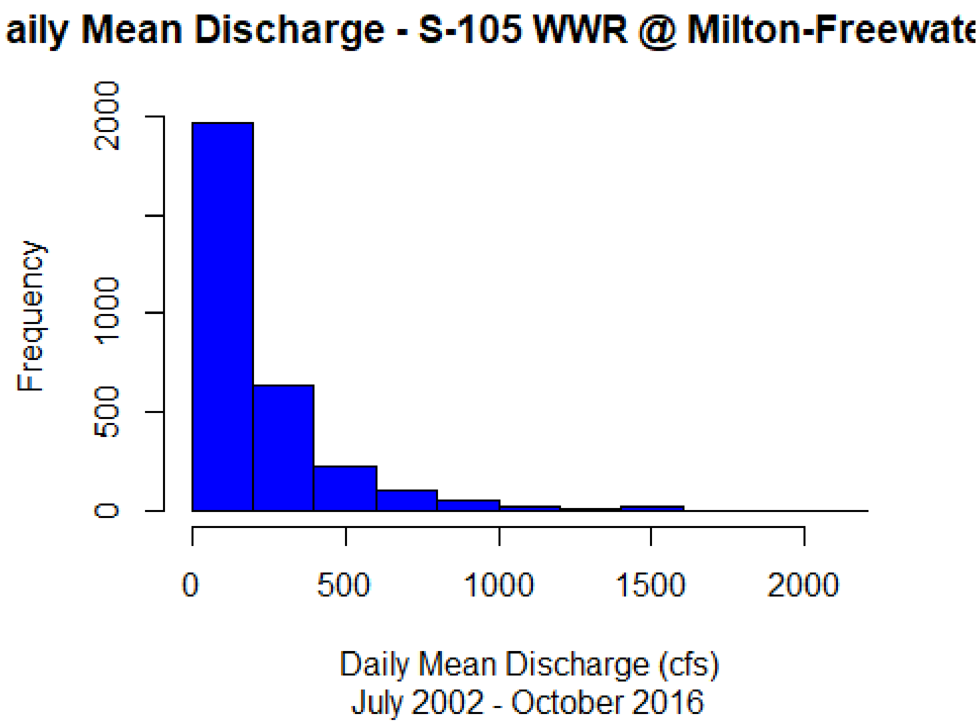
Visualizing the MeanDishcarge distribution hist plots a histogram of data

```
hist(s105Data$MeanDischarge)
```



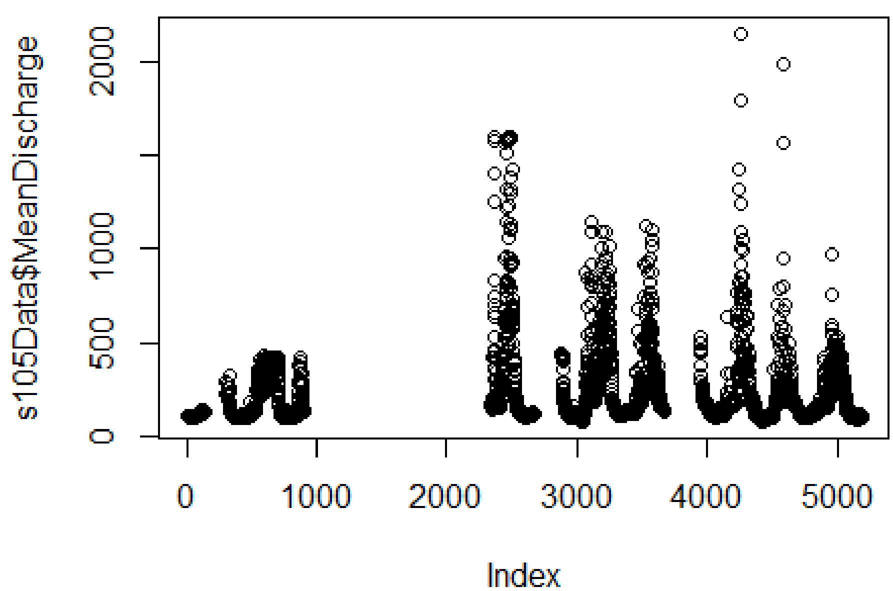
Create title and x-axis lables. The main argument changes the title The xlab argument changes the x-axis lable The sub argument adds a subtitle below the x-axis lable. The col argument changes the color of the bars

```
hist(s105Data$MeanDischarge,
     main = "Daily Mean Discharge - S-105 WWR @ Milton-Freewater, OR",
     xlab = "Daily Mean Discharge (cfs)",
     sub = "July 2002 - October 2016",
     col = "blue")
```

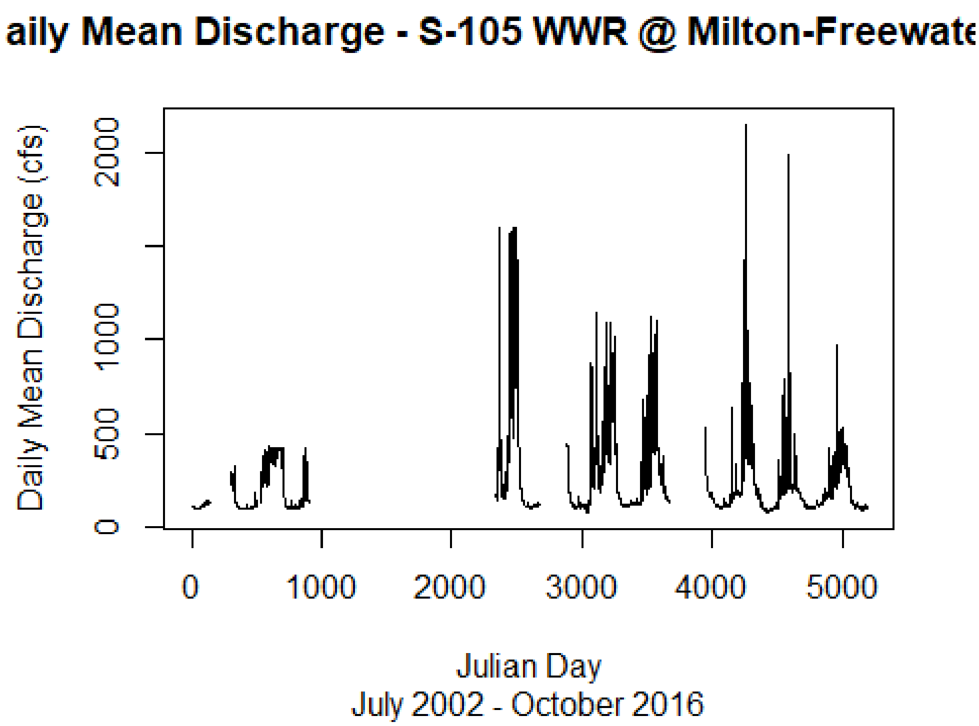


Plot Hydrograph

```
plot(s105Data$MeanDischarge)
```



```r
plot(s105Data$MeanDischarge,
     main = "Daily Mean Discharge - S-105 WWR @ Milton-Freewater, OR",
     xlab = "Julian Day",
     ylab = "Daily Mean Discharge (cfs)",
     sub = "July 2002 - October 2016",
     type = "l")
```



+++++MONTHLY STATISTICS++ Descriptive statistics and plots by groups Summary statistics by month Use the aggregate function to do the summary statistics. The first argument is a vector, martix, or data frame with data to aggregate. The by argument is a list of values to aggregate the data by. It's best to include a name. the last argument is the function to apply during aggregation. This function can only take one value. Since the na.rm argument must be set define an inline function that takes one argument and pass that to the summary statistic function. min

```r
aggregate(MeanDischarge ~ BiMonth, data = s105Data,
          function(x) min(x, na.rm = TRUE))

##   BiMonth MeanDischarge
## 1     1.0     122.72939
## 2     1.5     140.43459
## 3     2.0     147.88823
## 4     2.5     151.76339
## 5     3.0     178.24889
## 6     3.5     206.13590
## 7     4.0     197.92688
## 8     4.5     180.12253
```

```
## 9      5.0     147.41730
## 10     5.5     136.61449
## 11     6.0     108.93333
## 12     6.5      97.84173
## 13     7.0      94.89238
## 14     7.5      89.61708
## 15     8.0      79.72966
## 16     8.5      78.77461
## 17     9.0      80.39524
## 18     9.5      84.10655
## 19    10.0      93.46252
## 20    10.5      90.25554
## 21    11.0      74.83678
## 22    11.5      91.34141
## 23    12.0     118.32603
## 24    12.5     121.27594
```

Define a new function to calculate summary statistics

```
s105Summary <- function(x)
{
  #' calculate some summary statistics
  theMin <- min(x, na.rm = TRUE)
  theMax <- max(x, na.rm = TRUE)
  theMean <- round(mean(x, na.rm = TRUE), digits = 2)
  theVar <- round(var(x, na.rm = TRUE), digits = 2)
  theMedian <- median(x, na.rm = TRUE)
  theQuantile = quantile(x, probs = c(0.1,0.25,0.5,0.75, 0.9), na.rm = T)
  theN <- length(which(!is.na(x)))

  #' build the output vector
  out <- c(Min = theMin, Median = theMedian,
           Max = theMax, Mean = theMean, Quantile = theQuantile,
           Var = theVar, N = theN)
  return(out)
}
```

Use aggregate to create the summary then display it and export it

```
s105Summary <- aggregate(MeanDischarge ~ BiMonth, data = s105Data,
                         s105Summary)
s105Summary

##    BiMonth MeanDischarge.Min MeanDischarge.Median MeanDischarge.Max
## 1      1.0         122.72939            180.75754        1600.00000
## 2      1.5         140.43459            278.75007        1141.50034
## 3      2.0         147.88823            215.65565        1987.49222
## 4      2.5         151.76339            283.84897         970.99278
## 5      3.0         178.24889            304.37829        2154.32281
## 6      3.5         206.13590            414.81523        1572.54527
## 7      4.0         197.92688            465.58645        1581.63342
```

```
## 8      4.5         180.12253            400.79780        1600.00000
## 9      5.0         147.41730            384.09112        1600.00000
## 10     5.5         136.61449            255.40185        1430.46001
## 11     6.0         108.93333            222.05115        1011.05097
## 12     6.5          97.84173            174.01550         444.33201
## 13     7.0          94.89238            129.09330         203.83792
## 14     7.5          89.61708            108.30179         160.63375
## 15     8.0          79.72966            101.39002         135.41503
## 16     8.5          78.77461             99.09736         134.52777
## 17     9.0          80.39524            100.55505         155.80922
## 18     9.5          84.10655            105.27546         139.84302
## 19    10.0          93.46252            109.21819         154.03974
## 20    10.5          90.25554            109.63659         136.54177
## 21    11.0          74.83678            114.72616         180.55071
## 22    11.5          91.34141            129.69378         372.16544
## 23    12.0         118.32603            162.92647         879.41756
## 24    12.5         121.27594            193.13648         698.94655
##    MeanDischarge.Mean MeanDischarge.Quantile.10%
## 1           294.97000                 141.86134
## 2           342.30000                 167.22394
## 3           299.23000                 175.58672
## 4           330.05000                 175.37592
## 5           398.55000                 187.20647
## 6           472.20000                 290.62697
## 7           555.11000                 262.84643
## 8           504.35000                 199.13560
## 9           467.62000                 173.10711
## 10          382.35000                 150.53920
## 11          283.79000                 127.48246
## 12          191.58000                 108.15637
## 13          130.22000                 101.31755
## 14          113.16000                  96.91656
## 15          103.07000                  92.84980
## 16           99.03000                  87.77316
## 17          102.30000                  89.16546
## 18          104.72000                  93.40176
## 19          109.79000                  96.58554
## 20          110.98000                 100.96323
## 21          118.37000                  99.74450
## 22          140.13000                 106.83741
## 23          210.66000                 124.01479
## 24          227.50000                 123.98129
##    MeanDischarge.Quantile.25% MeanDischarge.Quantile.50%
## 1                   159.21484                  180.75754
## 2                   198.68726                  278.75007
## 3                   187.20470                  215.65565
## 4                   214.37771                  283.84897
## 5                   224.94534                  304.37829
## 6                   341.90461                  414.81523
## 7                   385.93483                  465.58645
```

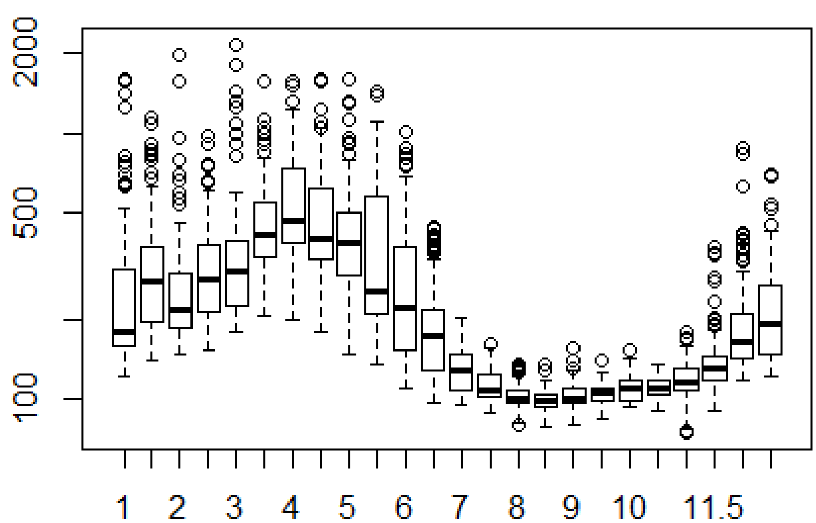
```
## 8                     338.87785                     400.79780
## 9                     294.13343                     384.09112
## 10                    209.74668                     255.40185
## 11                    152.45672                     222.05115
## 12                    129.37879                     174.01550
## 13                    108.44140                     129.09330
## 14                    101.69651                     108.30179
## 15                     96.81062                     101.39002
## 16                     93.48745                      99.09736
## 17                     96.37272                     100.55505
## 18                     99.17430                     105.27546
## 19                     98.95097                     109.21819
## 20                    104.38667                     109.63659
## 21                    108.63966                     114.72616
## 22                    118.49192                     129.69378
## 23                    143.13116                     162.92647
## 24                    148.31207                     193.13648
##    MeanDischarge.Quantile.75% MeanDischarge.Quantile.90% MeanDischarge.Var
## 1                     310.17590                     536.17203       74826.60000
## 2                     375.70537                     634.27055       43227.59000
## 3                     296.65996                     450.87039       64002.50000
## 4                     382.25334                     571.47134       29704.41000
## 5                     390.64510                     732.86171      112274.17000
## 6                     546.05920                     708.93772       44269.73000
## 7                     734.84612                     892.67510       76100.79000
## 8                     614.42587                     858.54267       89582.03000
## 9                     503.03304                     867.03550      102475.21000
## 10                    575.55485                     745.39707       75548.62000
## 11                    371.87822                     497.12697       32627.12000
## 12                    218.46773                     321.62461        6825.28000
## 13                    148.24162                     164.15192         638.29000
## 14                    123.61348                     141.04421         270.73000
## 15                    107.48322                     117.57907         122.50000
## 16                    103.74970                     110.31150          84.66000
## 17                    109.39619                     113.47031         122.15000
## 18                    110.56212                     114.12661          81.18000
## 19                    117.22219                     123.52591         133.29000
## 20                    117.47831                     121.59519          76.74000
## 21                    129.70582                     143.97406         372.70000
## 22                    144.58232                     179.94982        2174.18000
## 23                    208.21469                     353.50080       17249.04000
## 24                    266.31321                     364.34170       12149.11000
##    MeanDischarge.N
## 1        110.00000
## 2        104.00000
## 3        103.00000
## 4         91.00000
## 5        105.00000
## 6        112.00000
## 7        105.00000
```

```
## 8         104.00000
## 9         107.00000
## 10        119.00000
## 11        131.00000
## 12        150.00000
## 13        150.00000
## 14        175.00000
## 15        158.00000
## 16        160.00000
## 17        150.00000
## 18        150.00000
## 19        135.00000
## 20        137.00000
## 21        131.00000
## 22        120.00000
## 23         99.00000
## 24        112.00000
```

Export the table to a csv file

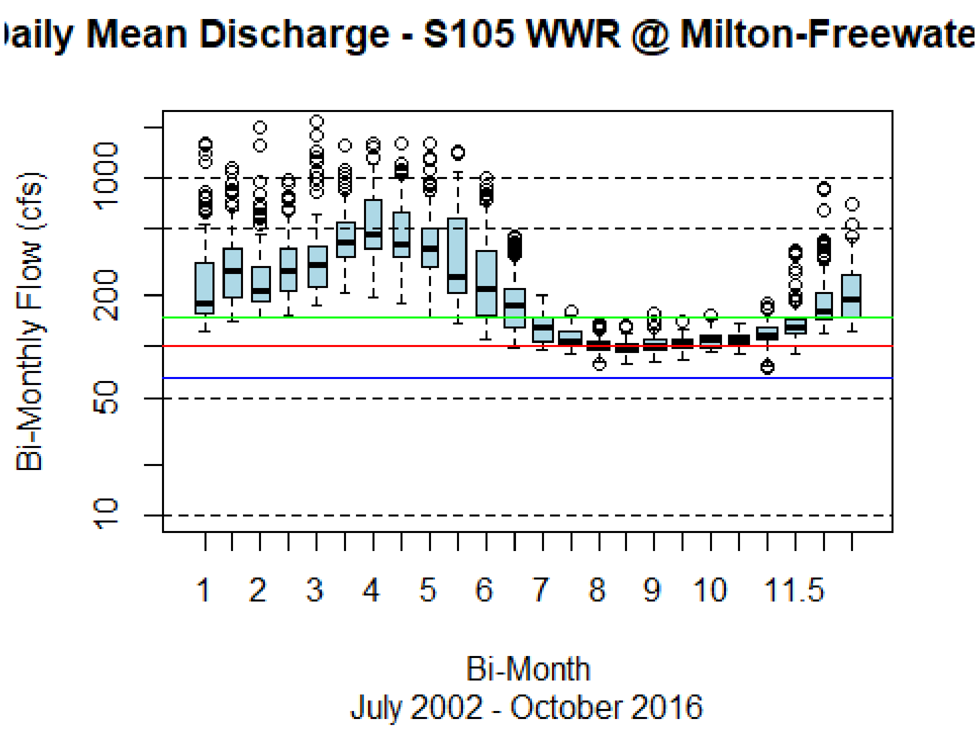
```
write.csv(s105Summary, file = "S105Summary.csv",
          row.names = FALSE)

boxplot(MeanDischarge ~ BiMonth, data = s105Data, log = "y")
```



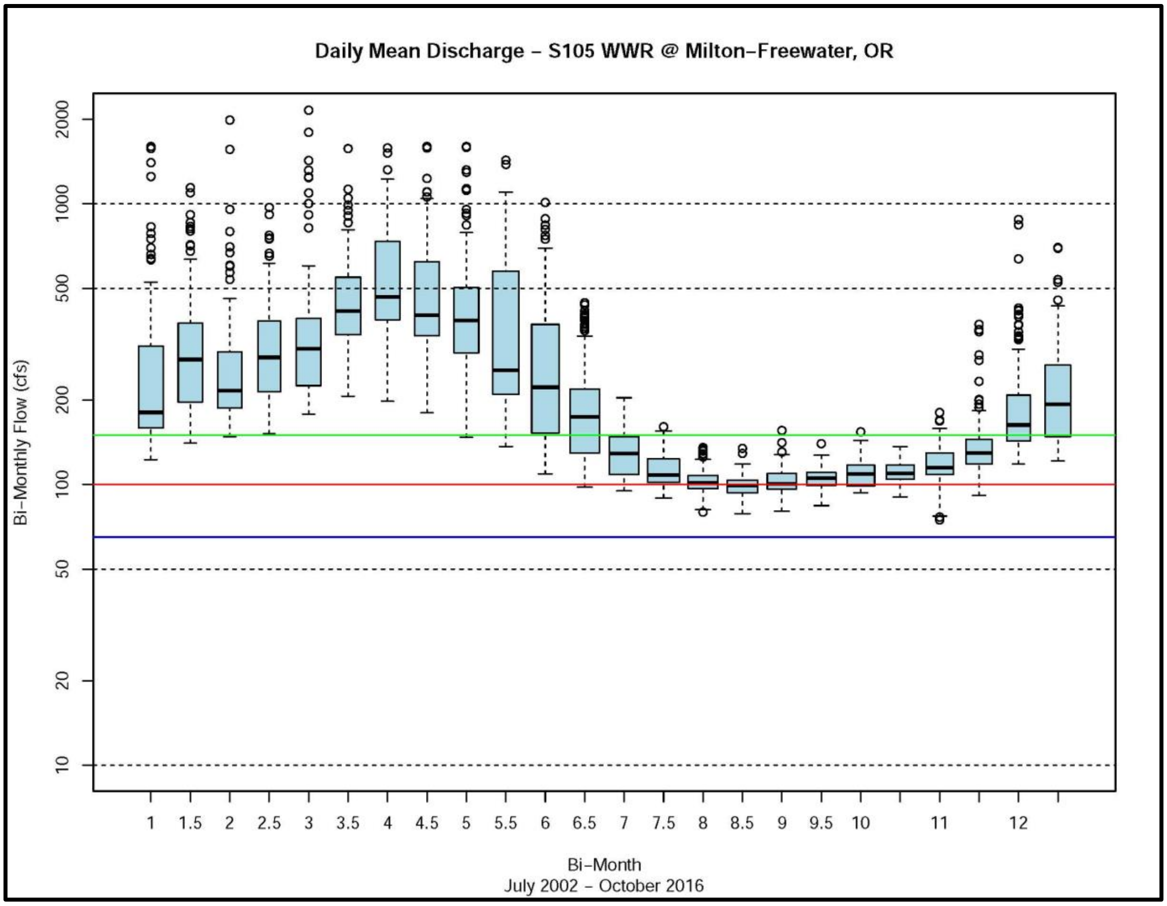
```r
boxplot(MeanDischarge ~ BiMonth, data = s105Data,
        main = "Daily Mean Discharge - S105 WWR @ Milton-Freewater, OR",
        sub = "July 2002 - October 2016",
        xlab = "Bi-Month", ylab = "Bi-Monthly Flow (cfs)",
        col = "lightblue", log = "y", ylim=c(10, 2001), cex.lab=1.00, varwidt
h = T)

abline(h=c(65), col = "blue")
abline(h=c(100), col = "red")
abline(h=c(150), col = "green")
abline(h=c(1,5,10,50,500,1000), lty=2, col = "black")
```



Appendix B – Current Instream Flow Analysis Results

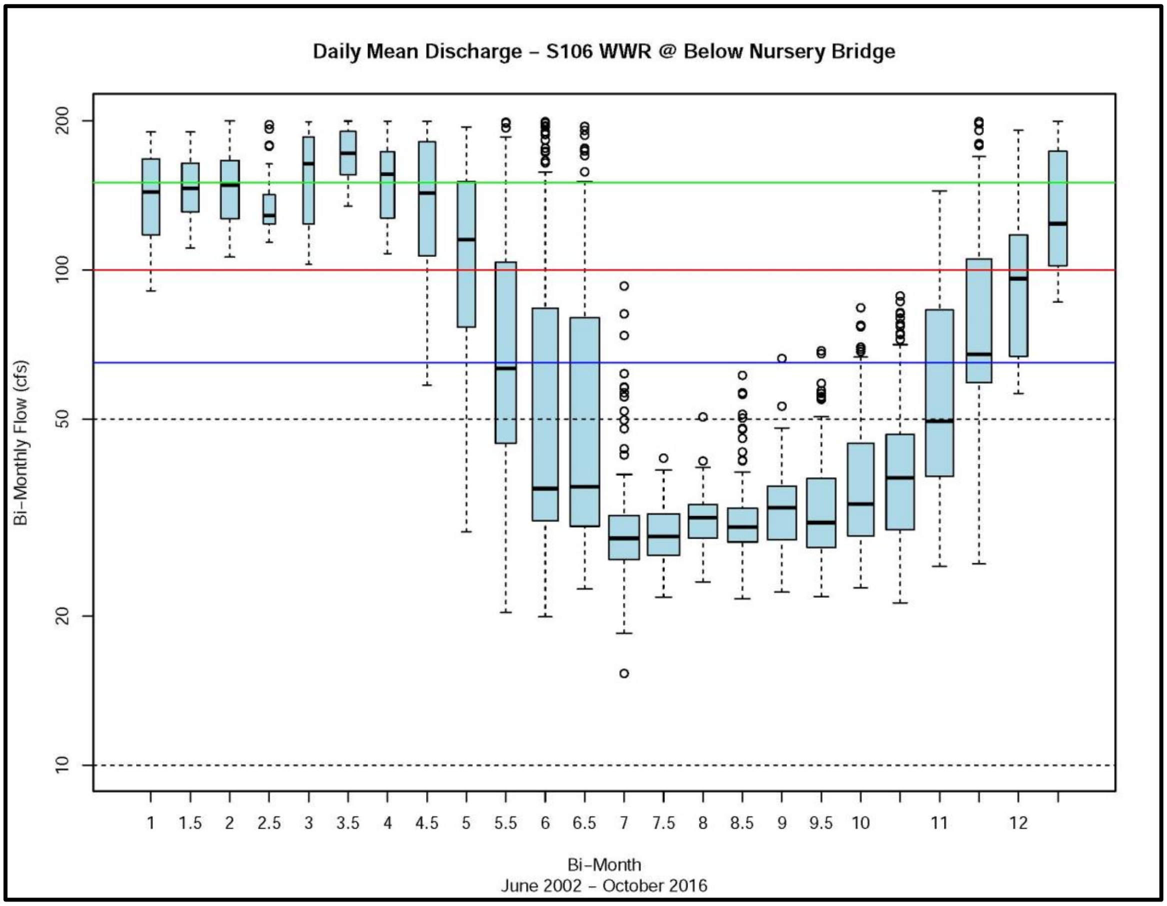
Walla Walla River @ Milton-Freewater, OR (S-105)



S-105 - Walla Walla River @ Milton-Freewater, OR

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	122.73	180.76	1600.00	294.97	141.86	159.21	180.76	310.18	536.17	74826.60	110
1.5	140.43	278.75	1141.50	342.30	167.22	198.69	278.75	375.71	634.27	43227.59	104
2	147.89	215.66	1987.49	299.23	175.59	187.20	215.66	296.66	450.87	64002.50	103
2.5	151.76	283.85	970.99	330.05	175.38	214.38	283.85	382.25	571.47	29704.41	91
3	178.25	304.38	2154.32	398.55	187.21	224.95	304.38	390.65	732.86	112274.17	105
3.5	206.14	414.82	1572.55	472.20	290.63	341.90	414.82	546.06	708.94	44269.73	112
4	197.93	465.59	1581.63	555.11	262.85	385.93	465.59	734.85	892.68	76100.79	105
4.5	180.12	400.80	1600.00	504.35	199.14	338.88	400.80	614.43	858.54	89582.03	104
5	147.42	384.09	1600.00	467.62	173.11	294.13	384.09	503.03	867.04	102475.21	107
5.5	136.61	255.40	1430.46	382.35	150.54	209.75	255.40	575.55	745.40	75548.62	119
6	108.93	222.05	1011.05	283.79	127.48	152.46	222.05	371.88	497.13	32627.12	131
6.5	97.84	174.02	444.33	191.58	108.16	129.38	174.02	218.47	321.62	6825.28	150
7	94.89	129.09	203.84	130.22	101.32	108.44	129.09	148.24	164.15	638.29	150
7.5	89.62	108.30	160.63	113.16	96.92	101.70	108.30	123.61	141.04	270.73	175
8	79.73	101.39	135.42	103.07	92.85	96.81	101.39	107.48	117.58	122.50	158
8.5	78.77	99.10	134.53	99.03	87.77	93.49	99.10	103.75	110.31	84.66	160
9	80.40	100.56	155.81	102.30	89.17	96.37	100.56	109.40	113.47	122.15	150
9.5	84.11	105.28	139.84	104.72	93.40	99.17	105.28	110.56	114.13	81.18	150
10	93.46	109.22	154.04	109.79	96.59	98.95	109.22	117.22	123.53	133.29	135
10.5	90.26	109.64	136.54	110.98	100.96	104.39	109.64	117.48	121.60	76.74	137
11	74.84	114.73	180.55	118.37	99.74	108.64	114.73	129.71	143.97	372.70	131
11.5	91.34	129.69	372.17	140.13	106.84	118.49	129.69	144.58	179.95	2174.18	120
12	118.33	162.93	879.42	210.66	124.01	143.13	162.93	208.21	353.50	17249.04	99
12.5	121.28	193.14	698.95	227.50	123.98	148.31	193.14	266.31	364.34	12149.11	112

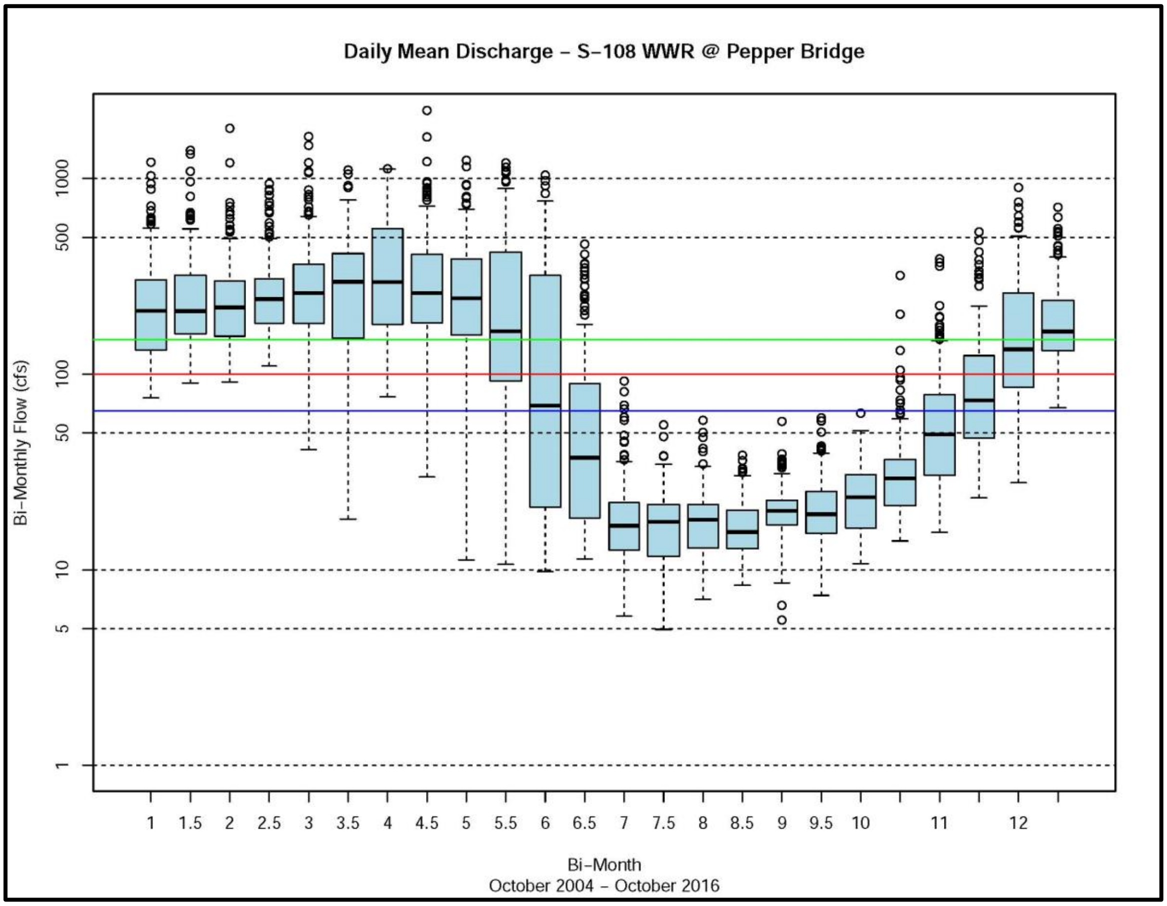
Walla Walla River Below Nursery Bridge (S-106)



S-106 - Walla Walla River Below Nursery Bridge

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	90.66	143.67	189.79	141.39	101.40	117.66	143.67	167.45	176.73	828.93	53
1.5	110.71	145.96	189.82	149.06	125.74	131.01	145.96	164.25	177.30	427.81	53
2	106.10	148.43	199.79	151.09	122.93	126.98	148.43	166.35	186.48	619.17	61
2.5	113.70	128.78	196.42	138.46	121.78	123.89	128.78	141.76	178.00	533.52	27
3	102.56	163.78	199.02	155.26	112.36	124.99	163.78	184.16	194.93	1078.75	22
3.5	134.56	171.96	199.71	172.32	146.74	155.75	171.96	190.17	195.72	386.14	44
4	107.88	155.88	199.66	153.48	117.75	127.30	155.88	173.20	189.04	707.53	35
4.5	58.48	142.82	199.61	141.99	85.30	106.69	142.82	181.37	191.72	1819.14	51
5	29.58	115.01	194.36	108.11	33.80	77.42	115.01	150.43	164.59	2324.05	60
5.5	20.35	63.27	198.66	80.44	33.32	45.19	63.27	101.92	166.71	2434.94	78
6	19.94	36.19	199.14	64.90	25.14	31.17	36.19	78.26	158.29	2833.24	120
6.5	22.69	36.51	194.76	58.77	25.70	30.39	36.51	79.47	122.58	1837.26	154
7	15.32	28.72	92.75	30.89	23.96	26.05	28.72	31.96	37.69	103.38	169
7.5	0.00	28.99	41.68	28.63	23.85	26.57	28.99	32.19	34.22	35.36	182
8	23.45	31.61	50.48	31.42	26.77	28.76	31.61	33.61	35.73	14.58	150
8.5	21.69	30.27	61.27	31.37	25.01	28.24	30.27	33.01	37.73	39.20	163
9	22.37	33.14	66.25	33.12	25.71	28.57	33.14	36.59	39.38	38.98	150
9.5	21.91	30.90	68.68	33.64	25.58	27.56	30.90	37.89	42.77	78.99	150
10	22.84	33.67	83.87	38.23	27.16	29.12	33.67	44.34	57.63	165.44	126
10.5	21.28	38.07	88.58	42.02	26.26	30.04	38.07	46.50	66.47	238.50	144
11	25.22	49.47	144.32	61.71	29.64	38.33	49.47	82.97	109.44	932.13	138
11.5	25.51	67.55	199.15	84.41	38.81	59.26	67.55	105.13	154.47	1880.18	119
12	56.30	95.99	191.39	98.58	63.70	67.11	95.99	116.17	144.31	1133.19	60
12.5	86.08	123.93	199.40	135.84	90.44	102.78	123.93	172.98	187.98	1405.40	60

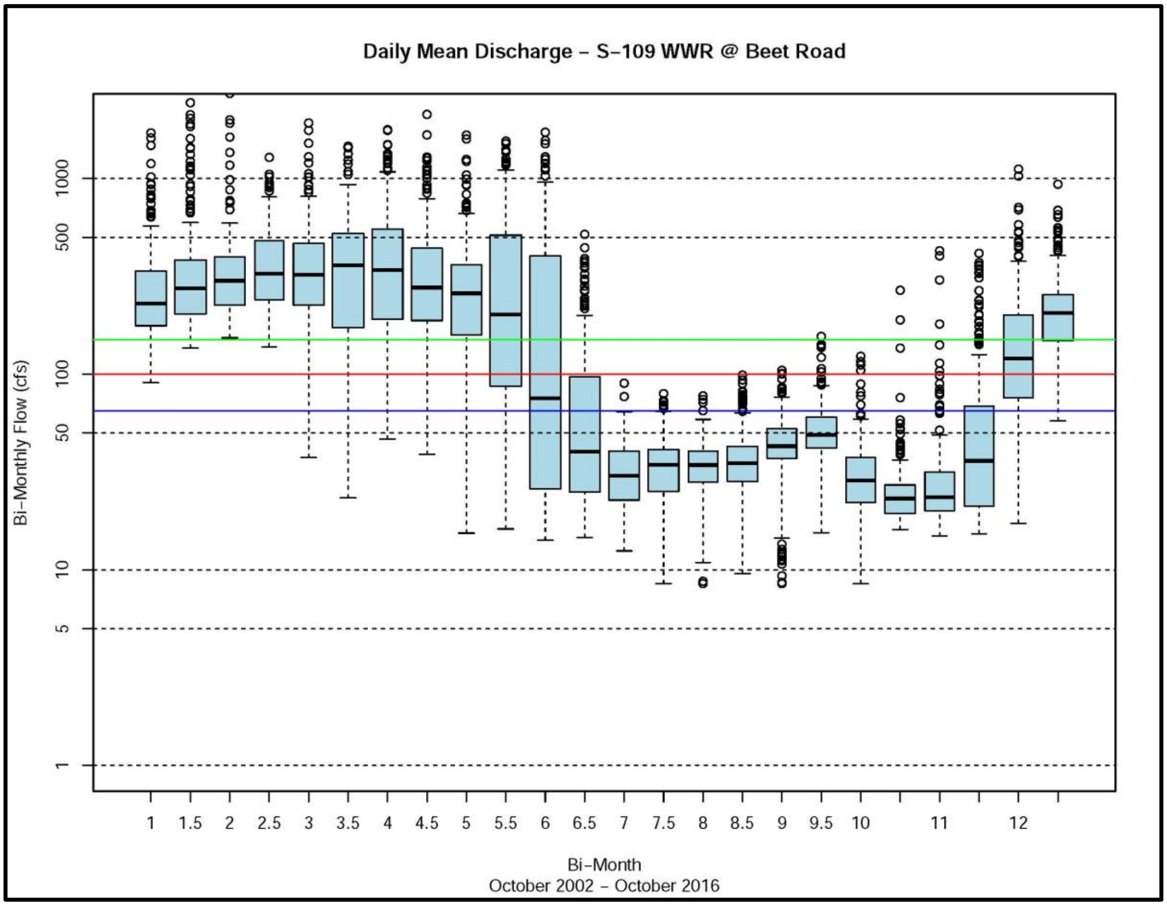
WALLA WALLA RIVER @ PEPPER BRIDGE (S-108)



S-108 - Walla Walla River @ Pepper Bridge

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	75.59	210.96	1212.39	257.09	112.90	133.18	210.96	303.30	486.14	31902.41	180
1.5	89.98	210.11	1393.85	276.46	118.94	161.17	210.11	320.03	493.28	37958.78	188
2	91.19	219.55	1808.01	264.17	128.37	157.39	219.55	298.85	441.37	34393.10	180
2.5	110.16	241.97	941.66	283.56	147.88	182.28	241.97	306.97	509.23	26886.00	158
3	41.14	259.70	1640.80	310.07	112.27	182.16	259.70	365.67	515.96	53342.50	180
3.5	18.16	296.79	1106.39	311.07	104.18	153.23	296.79	412.06	533.19	37046.32	192
4	76.50	295.27	1121.83	380.87	108.79	180.98	295.27	553.92	741.99	62203.67	180
4.5	29.82	259.97	2230.71	335.34	87.32	183.45	259.97	408.85	637.77	74911.89	180
5	11.24	244.12	1240.00	291.80	81.30	158.80	244.12	386.57	543.86	42840.76	180
5.5	10.65	165.41	1201.97	286.75	24.33	92.90	165.41	420.19	666.85	76240.51	192
6	9.80	68.98	1042.20	194.22	15.17	20.95	68.98	319.80	540.09	54196.58	180
6.5	11.35	37.43	462.42	77.28	15.02	18.41	37.43	88.98	213.04	8337.15	180
7	5.80	16.78	92.22	20.26	9.73	12.68	16.78	22.00	33.43	167.16	174
7.5	4.96	17.62	55.11	17.69	9.30	11.71	17.62	21.50	27.90	60.17	192
8	7.05	17.99	58.12	18.58	9.83	12.92	17.99	21.59	28.24	62.28	180
8.5	8.33	15.59	38.51	16.91	10.89	12.86	15.59	20.10	24.35	32.76	192
9	5.53	20.02	57.36	20.22	13.02	17.09	20.02	22.68	26.60	39.40	180
9.5	7.40	19.23	59.81	21.89	12.98	15.44	19.23	25.11	35.37	89.33	180
10	10.75	23.46	63.14	24.85	14.45	16.35	23.46	30.68	38.44	97.33	179
10.5	14.04	29.39	319.48	35.13	18.20	21.35	29.39	36.54	52.75	874.90	192
11	15.54	49.32	388.65	67.76	23.53	30.56	49.32	77.99	155.13	3593.59	180
11.5	23.29	73.49	534.05	105.39	34.30	47.23	73.49	124.43	209.18	8137.40	180
12	27.85	133.93	900.54	185.76	57.08	85.90	133.93	258.70	360.76	21602.11	180
12.5	67.47	165.13	713.61	201.13	96.28	132.06	165.13	236.63	350.73	12470.28	192

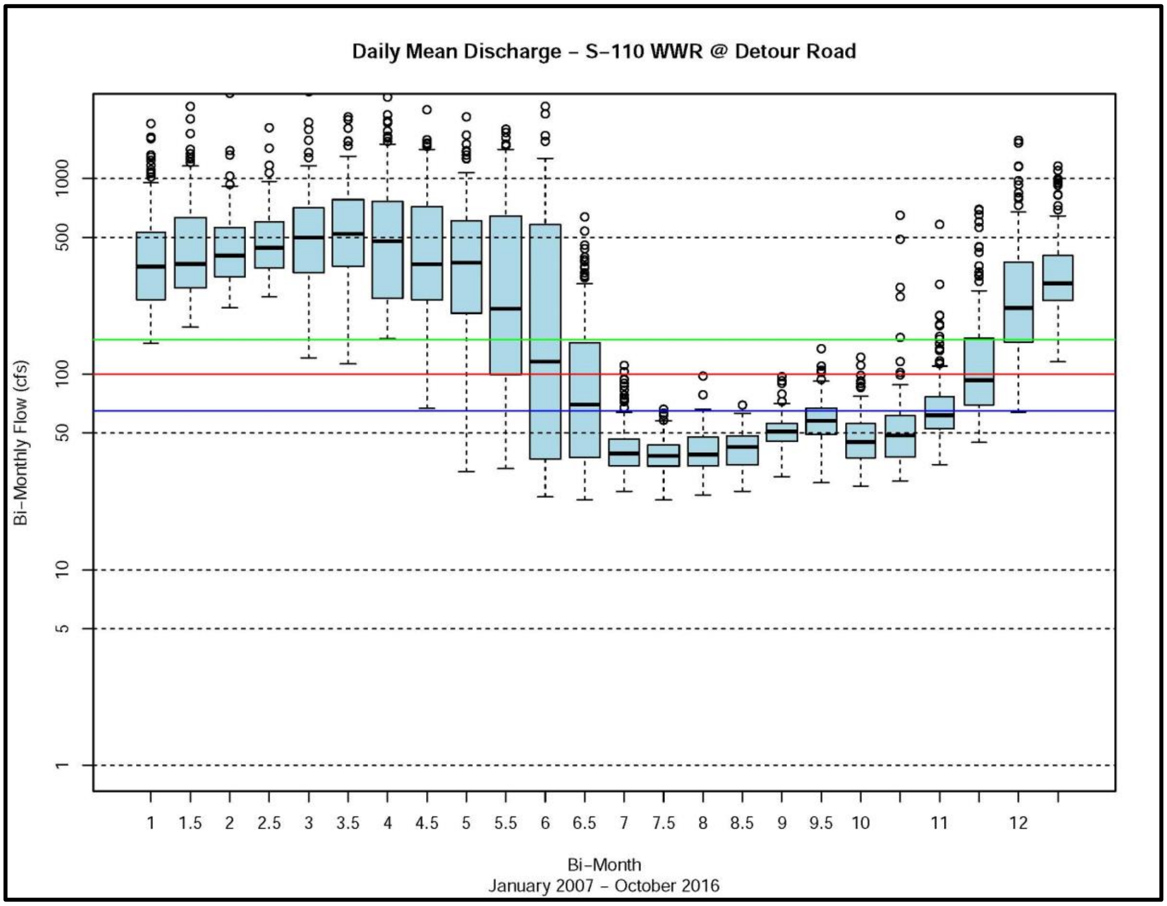
Walla Walla River @ Beet Road (S-109)



S-109 - Walla Walla River @ Beet Road

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	90.50	230.13	1712.60	307.48	154.60	176.93	230.13	335.72	555.48	59018.55	210
1.5	135.82	275.13	2441.93	385.92	164.54	202.94	275.13	384.29	684.36	129898.69	219
2	153.42	300.49	3788.49	388.76	186.68	225.39	300.49	398.48	544.72	143419.96	210
2.5	137.94	326.49	1283.23	391.61	217.33	240.57	326.49	479.33	675.41	44044.41	186
3	37.47	321.76	1924.53	382.88	137.28	225.08	321.76	466.76	657.31	75069.01	210
3.5	23.29	361.01	1462.55	387.07	73.70	174.36	361.01	521.35	735.32	76096.56	224
4	46.62	340.66	1778.65	435.14	101.59	192.50	340.66	551.58	880.80	113223.10	210
4.5	38.90	277.40	2129.06	362.33	116.84	188.19	277.40	435.25	734.82	86862.95	210
5	15.40	259.21	1670.05	304.75	75.57	159.06	259.21	362.40	550.35	61045.23	210
5.5	16.18	202.00	1553.96	344.73	29.39	86.84	202.00	513.37	906.83	126686.05	224
6	14.16	75.38	1725.57	249.71	21.96	25.94	75.38	402.46	645.78	108994.24	210
6.5	14.63	40.19	518.73	82.35	21.30	25.09	40.19	96.27	226.37	8555.18	210
7	12.49	30.30	89.93	33.08	18.88	22.70	30.30	40.51	52.05	176.79	205
7.5	8.50	34.50	79.51	34.15	12.90	25.15	34.50	41.25	51.57	212.36	208
8	8.50	34.30	77.45	33.81	17.30	28.04	34.30	40.37	46.68	138.65	195
8.5	9.58	35.04	98.89	38.14	24.64	28.33	35.04	42.70	57.30	241.64	208
9	8.50	42.87	104.60	45.70	29.65	37.12	42.87	52.80	67.09	325.16	195
9.5	15.48	48.90	156.00	53.74	33.06	41.98	48.90	60.33	73.64	499.14	206
10	8.50	28.68	123.42	32.59	17.47	22.05	28.68	37.62	50.47	308.72	195
10.5	16.06	23.12	268.58	27.49	17.75	19.41	23.12	27.12	35.71	542.31	208
11	14.90	23.54	427.66	36.26	17.99	20.06	23.54	31.64	63.94	2372.41	195
11.5	15.28	36.07	415.03	69.30	17.86	21.16	36.07	68.81	170.77	6276.85	195
12	17.29	120.38	1118.30	167.73	35.85	75.63	120.38	200.48	335.38	25015.43	195
12.5	57.73	205.32	936.24	228.67	117.11	148.71	205.32	255.17	363.21	15370.22	208

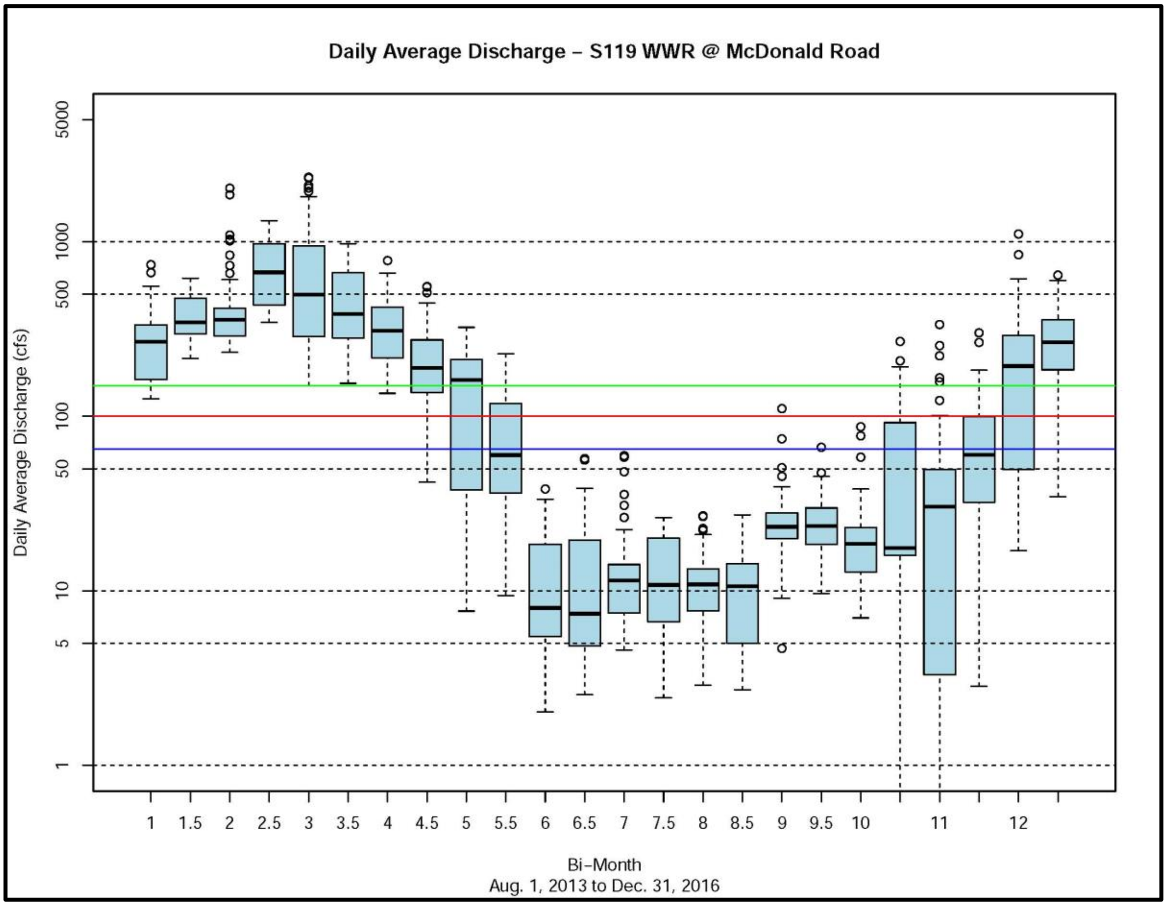
WALLA WALLA RIVER @ DETOUR ROAD (S-110)



S-110 - Walla Walla River @ Detour Road

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	144.00	355.00	3970.00	517.79	189.20	240.50	355.00	531.00	1044.00	302214.01	135
1.5	174.00	366.00	4440.00	532.43	228.70	276.75	366.00	628.75	940.40	257949.53	158
2	219.00	404.00	3280.00	492.92	267.10	315.75	404.00	561.50	693.40	125469.01	150
2.5	249.00	443.00	1820.00	513.92	310.60	349.00	443.00	602.00	789.60	54430.52	133
3	121.00	499.00	3030.00	579.51	218.00	333.25	499.00	707.75	944.20	167887.24	150
3.5	113.00	522.50	2070.00	600.93	170.70	358.25	522.50	779.00	1044.00	138106.40	160
4	152.00	478.50	2610.00	623.45	186.00	244.50	478.50	764.25	1401.00	229139.12	150
4.5	66.80	364.50	4600.00	541.23	178.60	240.50	364.50	716.75	1032.00	257526.36	150
5	31.70	371.50	2070.00	460.41	102.17	205.25	371.50	605.50	929.70	141713.49	150
5.5	32.90	216.00	1790.00	397.87	46.54	100.35	216.00	638.00	988.40	165797.84	160
6	23.60	116.00	2340.00	337.82	30.56	36.85	116.00	573.00	894.30	183451.93	150
6.5	22.80	69.80	637.00	116.31	32.29	37.63	69.80	144.50	311.40	13179.13	150
7	25.20	39.30	111.00	43.61	30.88	34.00	39.30	46.60	61.22	236.73	149
7.5	22.80	38.20	66.20	38.94	29.42	33.90	38.20	43.50	50.82	68.57	159
8	24.10	38.85	97.80	40.81	27.69	34.10	38.85	47.50	52.69	120.16	150
8.5	25.20	42.40	69.50	41.85	29.49	34.40	42.40	48.25	52.90	83.94	160
9	29.90	50.90	97.10	51.48	40.78	45.43	50.90	56.08	61.43	103.18	150
9.5	27.90	57.80	135.00	60.02	44.16	49.33	57.80	66.75	81.02	270.08	150
10	26.80	45.00	122.00	49.28	32.92	37.35	45.00	55.90	69.78	295.95	135
10.5	28.40	48.70	649.00	61.53	35.69	37.80	48.70	60.05	78.18	4687.46	144
11	34.50	61.60	583.00	76.03	42.96	52.70	61.60	76.50	111.80	3276.19	135
11.5	44.80	93.10	697.00	144.03	55.72	69.45	93.10	152.50	317.60	18195.73	135
12	63.80	218.00	1570.00	312.31	116.40	146.00	218.00	373.00	565.20	72643.17	133
12.5	116.00	291.50	1160.00	355.10	170.00	239.00	291.50	403.50	588.50	40713.32	144

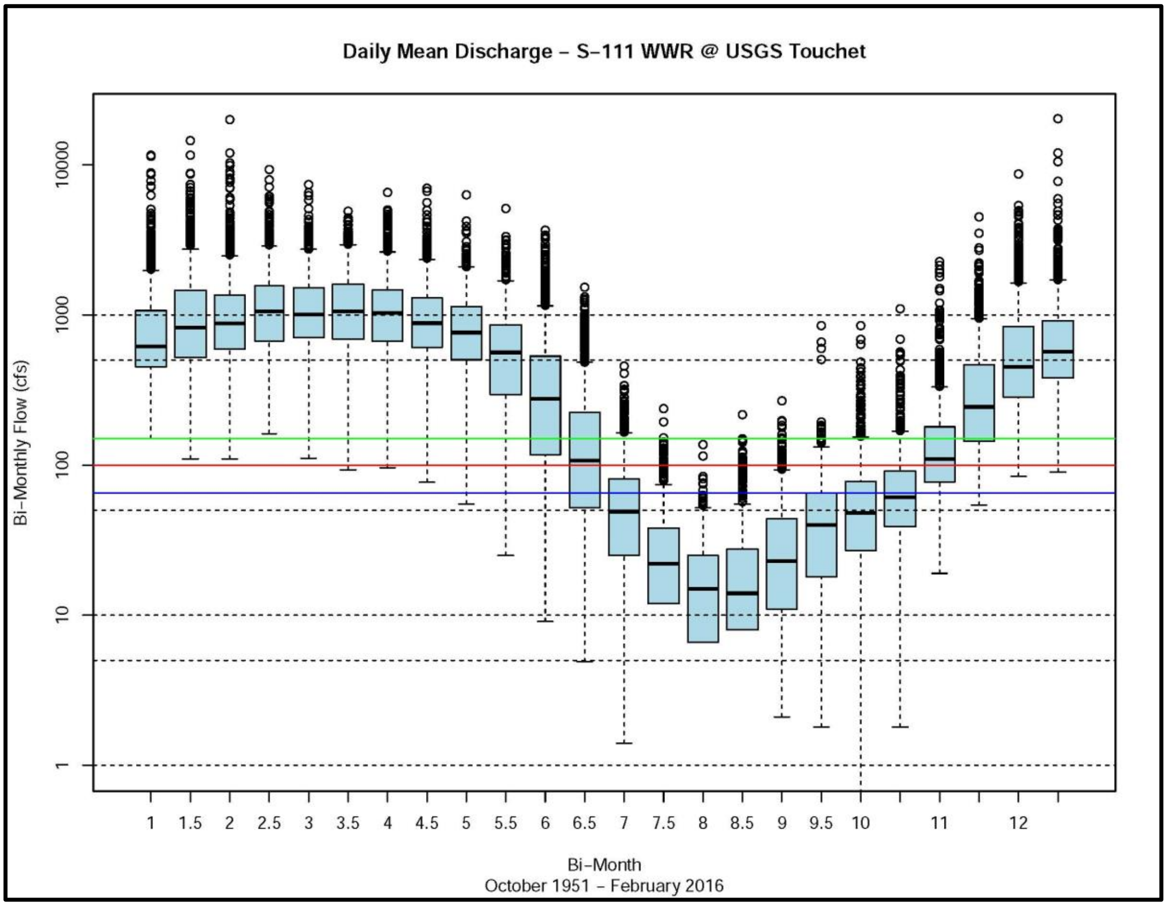
WALLA WALLA RIVER @ MCDONALD ROAD (S-119)



S-119 - Walla Walla River @ McDonald Road

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	125.72	267.91	738.59	290.26	149.63	162.13	267.91	334.28	539.92	23041.12	43
1.5	214.31	345.30	618.19	377.63	235.58	296.40	345.30	471.43	548.78	12960.74	48
2	232.26	356.59	2024.10	482.91	245.74	289.04	356.59	416.13	941.99	146913.88	45
2.5	345.39	667.38	1319.42	706.68	366.95	437.18	667.38	970.42	1081.57	86377.79	40
3	149.71	496.90	2339.94	772.94	210.53	286.20	496.90	945.79	1889.34	426687.07	45
3.5	154.36	385.14	972.94	467.66	182.43	283.26	385.14	657.79	873.01	63971.14	48
4	135.32	308.56	779.52	335.44	154.95	215.83	308.56	422.02	574.78	25283.99	45
4.5	41.87	188.87	553.85	213.01	63.39	136.71	188.87	273.81	366.26	16472.00	45
5	7.65	161.09	323.06	139.62	9.63	37.73	161.09	211.60	242.32	8624.27	45
5.5	9.39	59.88	227.91	77.25	23.46	36.43	59.88	115.86	148.08	2889.86	48
6	2.02	7.97	38.28	12.58	4.06	5.46	7.97	18.48	28.59	94.22	45
6.5	2.54	7.39	57.22	14.71	3.44	4.83	7.39	19.48	32.48	195.65	43
7	4.59	11.45	59.38	14.93	5.64	7.45	11.45	14.15	29.02	163.52	45
7.5	2.43	10.81	26.22	12.61	3.22	6.74	10.81	20.03	24.39	60.28	48
8	2.88	10.89	26.89	11.32	4.97	7.69	10.89	13.25	20.41	29.44	60
8.5	2.71	10.60	27.25	10.92	3.55	5.20	10.60	14.33	19.81	40.97	62
9	4.68	23.24	110.63	25.96	14.25	19.88	23.24	27.57	34.65	231.35	60
9.5	9.65	23.47	66.39	25.70	13.86	18.51	23.47	29.69	40.34	120.59	54
10	6.99	18.62	87.06	22.15	8.49	12.82	18.62	23.07	34.30	296.39	39
10.5	0.53	17.60	268.23	64.97	14.54	15.99	17.60	90.37	157.68	4524.95	34
11	0.53	30.27	335.45	48.22	0.71	6.90	30.27	49.15	107.78	4174.08	58
11.5	2.84	60.25	300.62	74.32	3.18	32.40	60.25	98.60	150.04	3810.92	60
12	17.00	193.94	1106.67	222.99	29.09	50.29	193.94	283.80	488.03	46011.33	60
12.5	34.66	265.21	643.46	270.77	111.29	185.69	265.21	356.99	456.90	18914.88	64

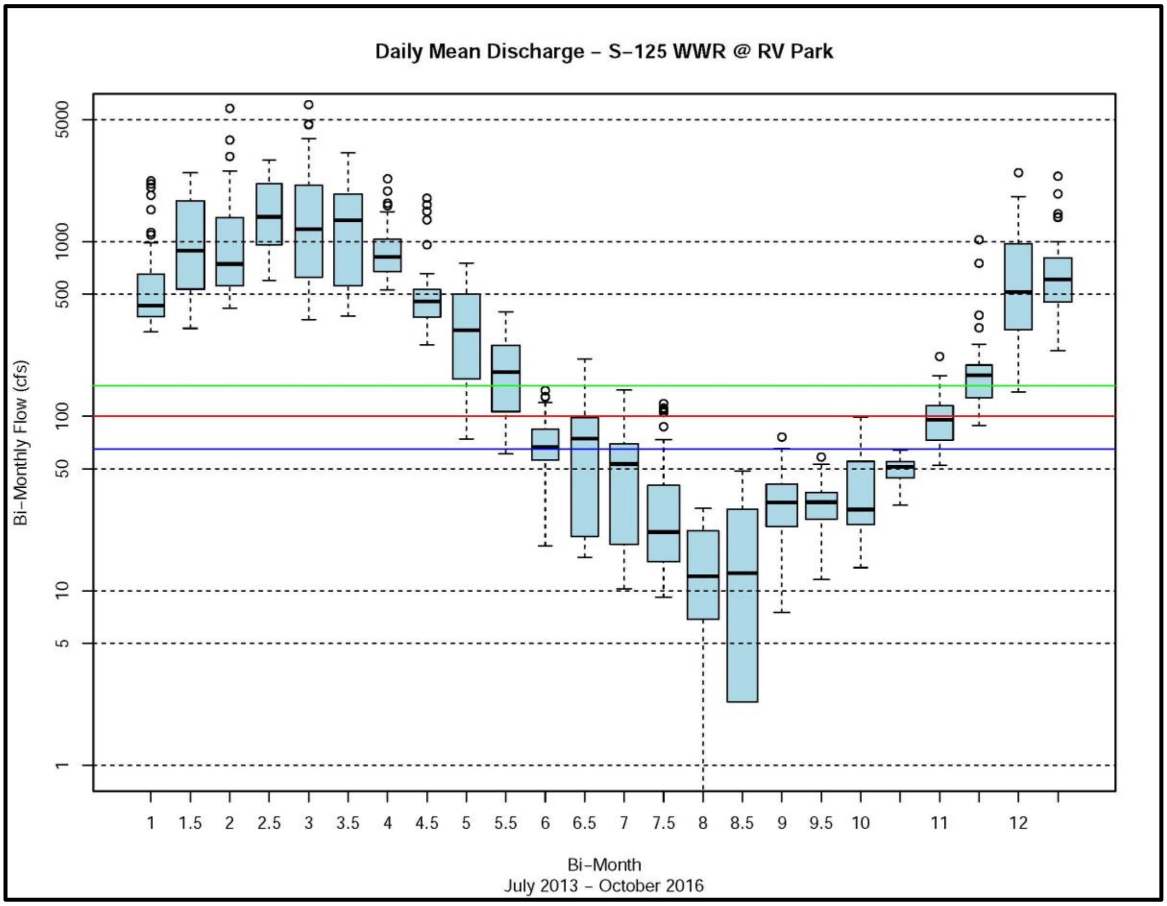
Walla Walla River Below Touchet River (S-111)



S-111 - Walla Walla River Below Touchet River

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	150.00	618.00	11600.00	952.71	332.00	452.00	618.00	1070.00	1820.00	1173098.91	975
1.5	110.00	824.50	14500.00	1225.32	389.80	520.00	824.50	1460.00	2460.00	1549126.06	1040
2	110.00	880.00	20000.00	1205.10	440.80	591.00	880.00	1360.00	2110.00	1676810.32	969
2.5	162.00	1060.00	9310.00	1315.73	477.40	670.00	1060.00	1570.00	2389.00	1027225.17	848
3	111.00	1010.00	7390.00	1225.80	500.00	705.00	1010.00	1520.00	2210.00	643629.13	960
3.5	93.00	1060.00	4910.00	1233.05	415.00	691.50	1060.00	1600.00	2210.00	601529.59	1024
4	96.00	1030.00	6550.00	1215.99	473.80	668.00	1030.00	1462.50	2250.00	643675.47	960
4.5	77.00	881.50	6990.00	1058.50	365.80	607.25	881.50	1302.50	1941.00	548723.55	960
5	55.00	764.00	6320.00	875.20	248.50	503.50	764.00	1140.00	1591.00	347818.67	960
5.5	25.00	563.00	5120.00	659.08	111.00	296.75	563.00	860.25	1290.00	274266.67	1024
6	9.10	276.50	3670.00	430.43	51.00	117.75	276.50	532.00	1021.00	249862.22	960
6.5	4.90	107.00	1530.00	179.16	25.00	52.00	107.00	225.00	416.20	41910.68	960
7	1.40	49.00	457.00	63.40	13.00	25.00	49.00	81.00	131.00	3179.18	960
7.5	0.00	22.00	238.00	28.89	6.20	12.00	22.00	38.00	56.00	635.49	1024
8	0.00	15.00	137.00	18.08	3.80	6.60	15.00	25.00	38.00	223.10	960
8.5	0.00	14.00	217.00	21.84	4.50	8.00	14.00	27.25	44.00	552.61	1024
9	2.10	23.00	268.00	31.89	7.00	11.00	23.00	44.00	68.00	870.99	960
9.5	1.80	40.00	850.00	48.81	6.79	18.00	40.00	65.00	98.10	2882.61	960
10	0.02	48.00	850.00	63.56	10.00	27.00	48.00	78.00	111.00	4859.48	960
10.5	1.80	61.00	1100.00	77.94	21.00	39.00	61.00	91.00	141.00	5766.32	1024
11	19.00	110.00	2270.00	165.44	54.00	77.00	110.00	180.00	300.20	41279.37	960
11.5	54.00	244.00	4500.00	382.81	100.90	144.00	244.00	467.25	850.40	163176.29	960
12	84.00	450.00	8690.00	702.16	189.80	284.00	450.00	837.00	1440.00	560524.18	960
12.5	90.00	570.00	20300.00	818.56	260.00	382.00	570.00	914.25	1501.00	1074789.79	1024

WALLA WALLA RIVER @ RV PARK (S-125)



S-125 - Walla Walla River @ RV Park

BiMonth	Minimum (cfs)	Median (cfs)	Maximum (cfs)	Mean (cfs)	Quantile.10%	Quantile.25%	Quantile.50%	Quantile.75%	Quantile.90%	Variance	Sample Size
1	303.87	430.34	2230.47	668.70	331.74	373.37	430.34	650.47	1367.08	261293.02	45
1.5	318.61	890.41	2480.66	1077.68	363.27	541.02	890.41	1650.29	2094.51	447666.85	48
2	416.53	745.41	5809.14	1173.79	476.02	557.94	745.41	1375.13	2238.33	1084685.45	45
2.5	599.77	1386.55	2933.86	1550.53	684.62	956.98	1386.55	2146.39	2453.55	474435.24	39
3	358.25	1176.61	6098.65	1645.65	469.68	624.79	1176.61	2105.42	3534.68	1771282.72	45
3.5	374.28	1323.38	3222.98	1389.25	500.78	562.62	1323.38	1844.79	2620.89	665146.61	48
4	530.85	817.29	2292.18	931.89	575.80	674.84	817.29	1031.94	1431.51	147438.47	45
4.5	256.61	453.72	1774.05	550.90	346.09	369.60	453.72	531.73	839.21	116499.04	45
5	74.15	311.47	753.67	332.61	80.83	163.47	311.47	499.46	609.59	40259.56	45
5.5	60.97	178.59	396.71	200.30	84.03	108.84	178.59	255.17	374.58	10659.25	48
6	18.11	66.64	140.33	70.38	33.76	56.10	66.64	83.86	114.65	849.81	44
6.5	15.56	74.63	212.73	70.43	17.00	20.51	74.63	98.04	116.30	2046.15	45
7	10.28	53.30	141.32	54.26	16.54	18.57	53.30	69.19	108.04	1297.72	50
7.5	9.18	21.73	118.22	34.29	10.92	14.66	21.73	40.17	87.14	895.68	61
8	0.41	12.12	29.63	14.13	2.05	6.97	12.12	21.87	25.60	74.88	60
8.5	0.00	12.61	48.55	16.71	0.22	2.78	12.61	29.10	41.36	231.51	56
9	7.50	32.10	75.99	31.98	12.72	23.45	32.10	40.67	44.92	182.94	60
9.5	11.58	32.17	58.41	32.33	19.99	25.92	32.17	36.44	46.09	100.16	60
10	13.58	29.23	98.54	38.81	14.73	23.94	29.23	55.14	67.19	473.31	45
10.5	30.92	51.33	64.16	49.42	39.97	44.40	51.33	54.79	57.37	59.48	48
11	52.38	95.71	219.97	100.25	64.30	72.93	95.71	115.34	153.86	1247.04	45
11.5	88.52	171.42	1026.45	203.51	115.40	127.45	171.42	196.54	258.14	27630.83	43
12	137.68	514.95	2484.82	703.53	156.32	312.45	514.95	973.26	1483.56	294385.31	45
12.5	237.11	608.70	2370.64	701.61	306.29	458.33	608.70	806.04	1113.77	172014.95	48

Download Link for Analysis Files (R files, PDF Graphs and Spreadsheets)

Download Zipped Folder

APPENDIX C – FLOOD FREQUENCY RESULTS

UPSTREAM OF POD

HydrologicStatsApp
"Upstream of POD"

Log Normal	mu=7.0981 sigma=0.398674
Pearson Type III	mu=1308.01 sigma=544.718 gamma=1.13954
Log Pearson Type III	mu=7.0981 sigma=0.405333 gamma=-0.00831455
Gamma	A=6.55887 B=199.426
Log Gamma	A=323.647 B=0.0219316
Gumbel	mu=1068.62 sigma=403.688
GEV	shape=0.064266 scale=393.149 location=1054.6
Weibull	A=1474.78 B=2.55282

Return Period	Log Normal	Pearson Type III	Log Pearson Type III	Gamma	Log Gamma	Gumbel	GEV	Weibull
2	1210	1207	1210	1242	1201	1217	1200	1278
5	1692	1711	1702	1707	1682	1674	1674	1777
10	2016	2038	2033	1990	2015	1977	2007	2045
15	2201	2219	2221	2142	2207	2148	2202	2179
20	2331	2343	2354	2245	2343	2268	2341	2267
25	2431	2438	2457	2323	2450	2360	2451	2331
50	2743	2725	2776	2556	2784	2644	2798	2516
100	3058	3003	3098	2778	3128	2926	3159	2682
200	3378	3274	3425	2991	3483	3206	3535	2834
500	3811	3624	3868	3263	3972	3577	4057	3017

HISTORIC DOWNSTREAM OF POD

HydrologicStatsApp
"Historic Downstream of POD"

Log Normal	mu=7.05658 sigma=0.431902
Pearson Type III	mu=1270.33 sigma=564.315 gamma=1.0948
Log Pearson Type III	mu=7.05658 sigma=0.440252 gamma=-0.13501
Gamma	A=5.68898 B=223.297
Log Gamma	A=271.441 B=0.0259967
Gumbel	mu=1021.5 sigma=420.922
GEV	shape=0.0559163 scale=411.374 location=1008.76
Weibull	A=1435.6 B=2.41763

Return Period	Log Normal	Pearson Type III	Log Pearson Type III	Gamma	Log Gamma	Gumbel	GEV	Weibull
2	A	1169	1172	1197	1150	1176	1161	1234
5	1669	1691	1685	1684	1660	1653	1652	1748
10	2018	2027	2026	1983	2020	1969	1995	2027
15	2219	2212	2219	2144	2231	2147	2195	2168
20	2361	2339	2353	2254	2382	2272	2338	2260
25	2472	2435	2456	2337	2500	2368	2450	2328
50	2817	2728	2775	2586	2875	2664	2802	2524
100	3170	3010	3093	2824	3265	2958	3167	2700
200	3530	3285	3411	3053	3672	3251	3544	2861
500	4023	3640	3834	3345	4241	3637	4065	3056

20% Reservoir Diversion

HydrologicStatsApp
"20% Reservoir Diversion"

Log Normal	mu=6.97311 sigma=0.467731
Pearson Type III	mu=1187.85 sigma=576.995 gamma=1.24991
Log Pearson Type III	mu=6.97311 sigma=0.474738 gamma=-0.058158
Gamma	A=4.84262 B=245.291
Log Gamma	A=226.481 B=0.030789
Gumbel	mu=936.247 sigma=418.347
GEV	shape=0.1134 scale=397.47 location=910.874
Weibull	A=1345.83 B=2.21597

Return Period	Log Normal	Pearson Type III	Log Pearson Type III	Gamma	Log Gamma	Gumbel	GEV	Weibull
2	1068	1071	1072	1107	1057	1090	1060	1141
5	1583	1607	1594	1602	1572	1564	1561	1668
10	1944	1961	1956	1911	1945	1878	1930	1961
15	2154	2158	2164	2078	2167	2055	2152	2110
20	2304	2294	2312	2192	2327	2179	2315	2208
25	2421	2398	2428	2279	2453	2274	2443	2281
50	2790	2715	2788	2538	2857	2569	2862	2491
100	3169	3023	3156	2787	3282	2861	3311	2681
200	3561	3324	3533	3028	3731	3152	3796	2856
500	4102	3715	4048	3336	4366	3536	4497	3069

30% Reservoir Diversion

HydrologicStatsApp
"30% Reservoir Diversion"

Log Normal	mu=6.94738 sigma=0.503735
Pearson Type III	mu=1173.74 sigma=592.695 gamma=1.12065
Log Pearson Type III	mu=6.94738 sigma=0.512636 gamma=-0.289957
Gamma	A=4.30629 B=272.565
Log Gamma	A=192.263 B=0.0361347
Gumbel	mu=912.041 sigma=440.92
GEV	shape=0.0711992 scale=427.716 location=895.063
Weibull	A=1330.18 B=2.13695

Return Period	Log Normal	Pearson Type III	Log Pearson Type III	Gamma	Log Gamma	Gumbel	GEV	Weibull
2	1040	1065	1066	1084	1028	1074	1054	1121
5	1590	1614	1611	1605	1580	1573	1572	1662
10	1984	1968	1971	1932	1992	1904	1939	1965
15	2216	2164	2173	2110	2240	2091	2155	2120
20	2383	2298	2313	2232	2420	2222	2310	2223
25	2513	2401	2420	2324	2563	2322	2431	2299
50	2928	2711	2749	2603	3025	2632	2819	2518
100	3358	3011	3071	2870	3519	2940	3223	2718
200	3808	3303	3389	3129	4047	3247	3646	2903
500	4435	3681	3805	3462	4805	3652	4238	3127

Appendix C
Water Supply Strategy Tables and Figures

Tables

Table 2.1a

Exceedance Value:Estimated Historic Flows at POD

Bi-weekly	Min	Median	Max	Average	90%	75%	50%	25%	10%
7-Oct	0	38	137	39	10	22	38	52	67
21-Oct	0	46	478	52	10	27	46	71	99
7-Nov	0	77	881	99	30	52	77	118	169
21-Nov	33	131	2747	178	64	95	131	204	304
7-Dec	70	161	1720	219	102	124	161	242	391
21-Dec	39	167	2132	217	101	128	167	238	389
7-Jan	0	192	2254	255	115	146	192	305	446
21-Jan	0	205	2074	288	124	159	205	311	542
7-Feb	0	220	3251	288	133	175	220	323	488
21-Feb	86	274	2384	322	143	204	274	363	522
7-Mar	29	310	1453	345	161	221	310	428	574
21-Mar	29	304	1226	333	138	200	304	409	567
7-Apr	47	296	1909	353	168	221	296	434	601
21-Apr	39	322	1698	361	162	233	322	426	613
7-May	18	293	1325	337	96	163	293	445	653
21-May	0	201	1140	231	38	78	201	338	475
7-Jun	-11	90	1216	139	31	47	90	172	298
21-Jun	0	50	565	67	24	36	50	70	126
7-Jul	5	48	182	49	23	35	48	57	67
21-Jul	7	52	141	50	30	42	52	58	65
7-Aug	12	51	108	50	31	41	51	57	65
21-Aug	4	47	118	45	27	35	47	54	59
7-Sep	4	40	110	40	19	29	40	50	57
21-Sep	-13	38	398	40	17	27	38	49	61

Data: Water Years 1970 through 2015

Table 2.1b

Exceedance Values: Modeled River Flows (cfs)at POD with 30% Incremental Storage Diversion

Bi-weekly	Min	Median	Max	Average	90%	75%	50%	25%	10%
7-Oct	34	74	103	72	74	74	74	74	74
21-Oct	32	74	386	77	70	74	74	74	90
7-Nov	42	86	649	104	70	70	86	111	151
21-Nov	48	113	2738	148	70	81	113	162	238
7-Dec	52	127	1610	172	81	101	127	188	291
21-Dec	44	127	2115	166	80	99	127	178	292
7-Jan	56	144	2253	197	88	110	144	225	335
21-Jan	74	156	2054	231	94	119	156	256	421
7-Feb	72	171	3238	235	100	128	171	266	398
21-Feb	71	220	2371	268	119	157	220	305	449
7-Mar	92	252	1444	302	143	177	252	374	536
21-Mar	93	281	1265	323	167	202	281	389	539
7-Apr	163	296	1940	357	188	225	296	432	586
21-Apr	140	313	1712	355	181	230	313	419	574
7-May	119	258	1126	323	159	169	258	413	594
21-May	86	175	1162	250	138	159	175	319	456
7-Jun	80	151	1260	175	106	114	151	169	270
21-Jun	75	112	547	104	75	75	112	114	114
7-Jul	35	75	189	77	75	75	75	75	75
21-Jul	35	75	101	74	75	75	75	75	75
7-Aug	35	75	82	74	75	75	75	75	75
21-Aug	34	75	133	73	74	74	75	75	75
7-Sep	34	74	80	72	74	74	74	74	74
21-Sep	34	74	397	73	74	74	74	74	74

Data: Water Years 1970 through 2015

Table 2.1c

Exceedance Values:Delta Table Modeled Flows (cfs) minus Historic Flows at POD

Bi-weekly	Min	Median	Max	Average	90%	75%	50%	25%	10%
7-Oct	34	36	-34	32	64	52	36	22	7
21-Oct	32	28	-92	25	60	47	28	3	-9
7-Nov	42	9	-232	5	40	18	9	-7	-18
21-Nov	15	-18	-9	-30	6	-14	-18	-42	-65
7-Dec	-18	-34	-110	-48	-21	-23	-34	-54	-100
21-Dec	5	-40	-17	-51	-21	-29	-40	-60	-97
7-Jan	56	-48	-1	-58	-27	-36	-48	-80	-111
21-Jan	74	-49	-20	-57	-30	-40	-49	-55	-121
7-Feb	72	-49	-13	-53	-33	-47	-49	-57	-89
21-Feb	-15	-54	-13	-54	-24	-48	-54	-59	-73
7-Mar	63	-58	-9	-43	-18	-44	-58	-54	-38
21-Mar	64	-23	39	-9	29	2	-23	-19	-28
7-Apr	116	0	31	5	20	4	0	-2	-15
21-Apr	101	-9	14	-6	19	-3	-9	-7	-39
7-May	102	-35	-199	-13	63	6	-35	-32	-59
21-May	86	-26	22	19	100	81	-26	-19	-19
7-Jun	91	62	44	36	75	67	62	-3	-28
21-Jun	75	62	-18	37	51	39	62	44	-12
7-Jul	30	27	7	29	52	40	27	19	8
21-Jul	28	23	-40	24	45	33	23	17	10
7-Aug	23	24	-26	24	44	34	24	18	10
21-Aug	30	28	15	28	47	39	28	21	16
7-Sep	30	34	-30	32	55	45	34	24	17
21-Sep	47	36	-1	32	57	47	36	25	13

Table 2.1d

Exceedance Values: Percentage Change of Project from Historic at POD

Bi-weekly	Min	Median	Max	Average	90%	75%	50%	25%	10%
7-Oct	*	93%	-25%	81%	627%	236%	93%	41%	10%
21-Oct	*	60%	-19%	48%	606%	176%	60%	4%	-9%
7-Nov	*	11%	-26%	6%	135%	34%	11%	-6%	-11%
21-Nov	46%	-14%	0%	-17%	10%	-15%	-14%	-20%	-22%
7-Dec	-25%	-21%	-6%	-22%	-21%	-19%	-21%	-22%	-26%
21-Dec	13%	-24%	-1%	-23%	-21%	-23%	-24%	-25%	-25%
7-Jan	*	-25%	0%	-23%	-23%	-25%	-25%	-26%	-25%
21-Jan	*	-24%	-1%	-20%	-24%	-25%	-24%	-18%	-22%
7-Feb	*	-22%	0%	-18%	-25%	-27%	-22%	-18%	-18%
21-Feb	-18%	-20%	-1%	-17%	-17%	-23%	-20%	-16%	-14%
7-Mar	215%	-19%	-1%	-12%	-11%	-20%	-19%	-13%	-7%
21-Mar	218%	-8%	3%	-3%	21%	1%	-8%	-5%	-5%
7-Apr	249%	0%	2%	1%	12%	2%	0%	0%	-2%
21-Apr	259%	-3%	1%	-2%	11%	-1%	-3%	-2%	-6%
7-May	580%	-12%	-15%	-4%	65%	4%	-12%	-7%	-9%
21-May	*	-13%	2%	8%	261%	104%	-13%	-6%	-4%
7-Jun	-821%	69%	4%	26%	244%	143%	69%	-2%	-9%
21-Jun	*	124%	-3%	56%	213%	109%	124%	63%	-10%
7-Jul	548%	58%	4%	59%	231%	114%	58%	33%	13%
21-Jul	386%	45%	-28%	47%	149%	80%	45%	29%	15%
7-Aug	189%	47%	-24%	48%	142%	82%	47%	31%	16%
21-Aug	729%	60%	13%	62%	178%	114%	60%	38%	26%
7-Sep	819%	85%	-28%	81%	283%	154%	85%	49%	30%
21-Sep	-354%	94%	0%	80%	340%	174%	94%	50%	22%

* for these occurences the minimum flow in the river was 0 cfs so a % increase is meaningless

Table 2.2 Modeled 25 Percent Exceedance Flows at POD to Touchet: "Wet" conditions

ESTIMATED BIWEEKLY 25% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE-POD - HISTORIC (WY 2002 to 2016)																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	52	71	118	204	242	238	305	311	323	363	428	409	434	426	445	338	172	70	57	58	57	54	50	49
Cemetery to Nursery Bridge	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**
NURSERY BRIDGE	46	63	104	179	212	209	268	273	283	319	375	359	408	400	418	318	162	66	50	51	50	48	44	43
Nursery Bridge to Pepper	**-47%**	**-47%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-30%**	**-30%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**
PEPPER BRIDGE	24	33	83	143	170	167	214	218	227	255	300	287	326	320	335	254	113	46	26	27	27	25	23	23
Pepper Bridge to Beet Road	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
BEET ROAD	25	34	85	146	173	170	218	223	231	260	306	293	333	327	341	259	115	47	27	28	27	26	24	23
Beet Road to Detour Road	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
DETOUR ROAD	25	34	85	146	173	170	218	223	231	260	306	293	333	327	341	259	115	47	27	28	27	26	24	23
MILL CREEK INFLOW	37	45	62	110	129	120	173	172	163	191	224	227	196	171	164	130	89	51	38	33	32	32	33	35
Detour Rd to McDonald Rd	**-16%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**
MCDONALD ROAD	57	76	140	244	288	276	373	377	376	431	506	496	502	472	478	369	195	94	60	56	55	54	53	55
McDonald Rd to Touchet	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
TOUCHET	48	61	110	244	*288*	*276*	*373*	*376*	*375*	*430*	*505*	*496*	1030	882	764	563	277	107	49	22	15	14	23	40

ESTIMATED BIWEEKLY 25% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE (POD) - 30% STORAGE DIVERSION																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	74	74	111	181	224	211	274	275	286	322	384	392	433	427	435	329	169	114	75	75	75	75	74	74
Cemetery to Nursery Bridge	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**
NURSERY BRIDGE	65	65	97	159	197	185	241	242	251	283	337	344	407	401	409	309	159	107	66	66	66	66	65	65
Nursery Bridge to Pepper	**-47%**	**-47%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-30%**	**-30%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**
PEPPER BRIDGE	34	34	78	127	157	148	192	193	201	226	270	275	326	321	327	247	111	75	35	35	35	35	34	34
Pepper Bridge to Beet Road	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
BEET ROAD	35	35	80	130	160	151	196	197	205	231	275	281	332	328	334	252	113	77	36	36	36	36	35	35
Beet Road to Detour Road	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
DETOUR ROAD	35	35	80	130	160	151	196	197	205	231	275	281	332	328	334	252	113	77	36	36	36	36	35	35
MILL CREEK INFLOW	37	45	62	110	129	120	173	172	163	191	224	227	196	171	164	130	89	51	38	33	32	32	33	35
Detour Rd to McDonald Rd	**-16%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**
MCDONALD ROAD	66	77	135	229	277	258	353	353	352	403	477	485	501	473	471	362	194	121	68	63	62	62	63	64
McDonald Rd to Touchet	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
TOUCHET	48	61	110	244	*295*	*275*	*376*	*376*	*374*	*429*	*508*	*516*	1030	882	764	563	277	107	49	22	15	14	23	40

Table 2.3
Modeled 50 Percent Exceedance Flows at POD to Touchet: "Average" conditions

ESTIMATED BIWEEKLY 50% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE-POD - HISTORIC (WY 2002 to 2016)																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	38	46	77	131	161	167	192	205	220	274	310	304	296	322	293	201	90	50	48	52	51	47	40	38
Cemetery to Nursery Bridge	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-6%	-6%	-6%	-6%	-6%	-6%	-12%	-12%	-12%	-12%	-12%	-12%
NURSERY BRIDGE	34	41	68	115	141	146	169	180	193	241	272	267	278	303	275	189	84	47	42	45	45	41	35	34
Nursery Bridge to Pepper	-47%	-47%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-30%	-30%	-47%	-47%	-47%	-47%	-47%	-47%
PEPPER BRIDGE	18	22	54	92	113	117	135	144	155	192	218	214	223	242	220	151	59	33	22	24	24	22	19	18
Pepper Bridge to Beet Road	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
BEET ROAD	18	22	55	94	115	119	138	147	158	196	222	218	227	247	225	154	60	33	23	24	24	22	19	18
Beet Road to Detour Road	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
DETOUR ROAD	18	22	55	94	115	119	138	147	158	196	222	218	227	247	225	154	60	33	23	24	24	22	19	18
MILL CREEK INFLOW	31	35	46	65	75	70	86	96	97	129	147	148	138	124	110	87	61	40	32	30	29	29	29	30
Detour Rd to McDonald Rd	-16%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-16%	-16%	-16%	-16%	-16%	-16%
MCDONALD ROAD	46	55	97	151	181	180	213	231	242	309	351	348	347	351	317	229	116	71	51	50	49	48	45	45
McDonald Rd to Touchet	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
TOUCHET	48	61	110	244	*293*	*291*	*344*	*374*	*392*	*500*	*567*	*563*	1030	882	764	563	277	107	49	22	15	14	23	40

ESTIMATED BIWEEKLY 50% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE (POD) - 30% STORAGE DIVERSION																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	74	74	86	113	127	127	144	156	171	220	252	281	296	313	258	175	151	112	75	75	75	75	74	74
Cemetery to Nursery Bridge	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-12%	-6%	-6%	-6%	-6%	-6%	-6%	-12%	-12%	-12%	-12%	-12%	-12%
NURSERY BRIDGE	65	65	76	99	112	112	126	137	150	193	221	247	278	294	243	165	142	105	66	66	66	66	65	65
Nursery Bridge to Pepper	-47%	-47%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-20%	-30%	-30%	-47%	-47%	-47%	-47%	-47%	-47%
PEPPER BRIDGE	34	34	60	79	89	89	101	110	120	155	177	197	223	235	194	132	99	74	35	35	35	35	34	34
Pepper Bridge to Beet Road	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
BEET ROAD	35	35	62	81	91	91	103	112	123	158	181	201	227	240	198	134	101	75	36	36	36	36	35	35
Beet Road to Detour Road	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
DETOUR ROAD	35	35	62	81	91	91	103	112	123	158	181	201	227	240	198	134	101	75	36	36	36	36	35	35
MILL CREEK INFLOW	31	35	46	65	75	70	86	96	97	129	147	148	138	124	110	87	61	40	32	30	29	29	29	30
Detour Rd to McDonald Rd	-16%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-16%	-16%	-16%	-16%	-16%	-16%
MCDONALD ROAD	61	67	102	139	159	154	181	199	210	274	313	333	347	345	292	211	154	109	62	60	59	59	59	59
McDonald Rd to Touchet	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
TOUCHET	48	61	110	244	*278*	*270*	*318*	*349*	*368*	*480*	*549*	*584*	1030	882	764	563	277	107	49	22	15	14	23	40

Table 2.4
Modeled 75 Percent Exceedance Flows at POD to Touchet: "Dry" conditions

ESTIMATED BIWEEKLY 75% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE-POD - HISTORIC (WY 2002 to 2016)																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	22	27	52	95	124	128	146	159	175	204	221	200	221	233	163	78	47	36	35	42	41	35	29	27
Cemetery to Nursery Bridge	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**
NURSERY BRIDGE	19	24	46	84	109	112	128	139	153	180	194	175	207	219	153	73	44	34	31	37	36	30	26	24
Nursery Bridge to Pepper	**-47%**	**-47%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-30%**	**-30%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**
PEPPER BRIDGE	10	12	37	67	87	90	102	111	123	144	156	140	166	175	123	59	31	24	16	19	19	16	14	13
Pepper Bridge to Beet Road	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
BEET ROAD	10	13	37	68	89	92	104	114	125	146	159	143	169	179	125	60	32	24	17	20	20	16	14	13
Beet Road to Detour Road	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
DETOUR ROAD	10	13	37	68	89	92	104	114	125	146	159	143	169	179	125	60	32	24	17	20	20	16	14	13
MILL CREEK INFLOW	27	28	37	41	48	50	58	65	64	85	96	106	104	93	78	60	41	33	29	27	25	25	25	27
Detour Rd to McDonald Rd	**-16%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**
MCDONALD ROAD	36	40	71	104	130	135	154	170	179	220	242	238	259	257	193	115	70	55	43	44	41	39	37	37
McDonald Rd to Touchet	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
TOUCHET	48	61	110	244	*304*	*316*	*361*	*398*	*420*	*516*	*567*	*558*	1030	882	764	563	277	107	49	22	15	14	23	40

ESTIMATED BIWEEKLY 75% EXCEEDANCE FLOWS FOR REACHES DOWNSTREAM OF CEMETERY BRIDGE (POD) - 30% STORAGE DIVERSION																								
	OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
CEMETERY BRIDGE - POD	74	74	70	81	101	99	110	119	128	157	177	202	225	230	169	159	114	75	75	75	75	74	74	74
Cemetery to Nursery Bridge	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-6%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**	**-12%**
NURSERY BRIDGE	65	65	61	71	89	87	97	104	112	137	155	177	212	216	159	149	107	71	66	66	66	65	65	65
Nursery Bridge to Pepper	**-47%**	**-47%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-20%**	**-30%**	**-30%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**	**-47%**
PEPPER BRIDGE	34	34	49	57	71	69	77	84	90	110	124	142	169	173	127	120	75	49	35	35	35	34	34	34
Pepper Bridge to Beet Road	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
BEET ROAD	35	35	50	58	72	71	79	85	92	112	127	145	173	176	130	122	77	50	36	36	36	35	35	35
Beet Road to Detour Road	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
DETOUR ROAD	35	35	50	58	72	71	79	85	92	112	127	145	173	176	130	122	77	50	36	36	36	35	35	35
MILL CREEK INFLOW	27	28	37	41	48	50	58	65	64	85	96	106	104	93	78	60	41	33	29	27	25	25	25	27
Detour Rd to McDonald Rd	**-16%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-8%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**
MCDONALD ROAD	57	60	83	95	114	115	130	144	148	188	212	239	263	255	198	172	111	79	59	57	55	55	55	56
McDonald Rd to Touchet	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**
TOUCHET	48	61	110	244	*295*	*298*	*336*	*371*	*383*	*486*	*548*	*617*	1030	882	764	563	277	107	49	22	15	14	23	40

Table 2.5
Maximum changes in wetted width using the largest differences in flow between the Project exceedance flows and Historic

Exceedance Level (Date of largest flow difference)	Project Flow (cfs)	Historic Flow (cfs)	Difference (cfs)	Changes in Wetted Width as a Result of Reduction in Flow (feet)[1]		
				Study Reach 1	Study Reach 2	Study Reach 3
90 % (7-Feb)	100	133	-33	49.5 - 50.7 = **-1.2 feet**	60.6 - 62.1= **-1.5 feet**	47.3 - 50.3= **-3.0 feet**
75 % (21-Feb)	157	204	-48	52.2 - 55.6= **-3.4 feet**	62.9 - 64.1= **-1.2 feet**	53.0 - 58.2= **-5.2 feet**
50 % (7-Mar)	252	310	-63	57.1 - 58.4= **-1.3 feet**	65.4 - 67.0= **-1.6 feet**	62.9 - 65.8 = **-2.9 feet**
25 % (7-Jan)	225	305	-80	56.3 - 58.3= **-2.0 feet**	64.6- 66.8= **-2.2 feet**	65.1 - 65.7 = **-0.6 feet**
10 % (21-Jan)	421	542	-121	Out of data range	Out of data range	Out of data range

[1] Wetted width associated with historic flow (minus) Wetted width associated Project flow per the relationships between wetted width and flow for three study sites in the instream flow study by WDOE (2002).

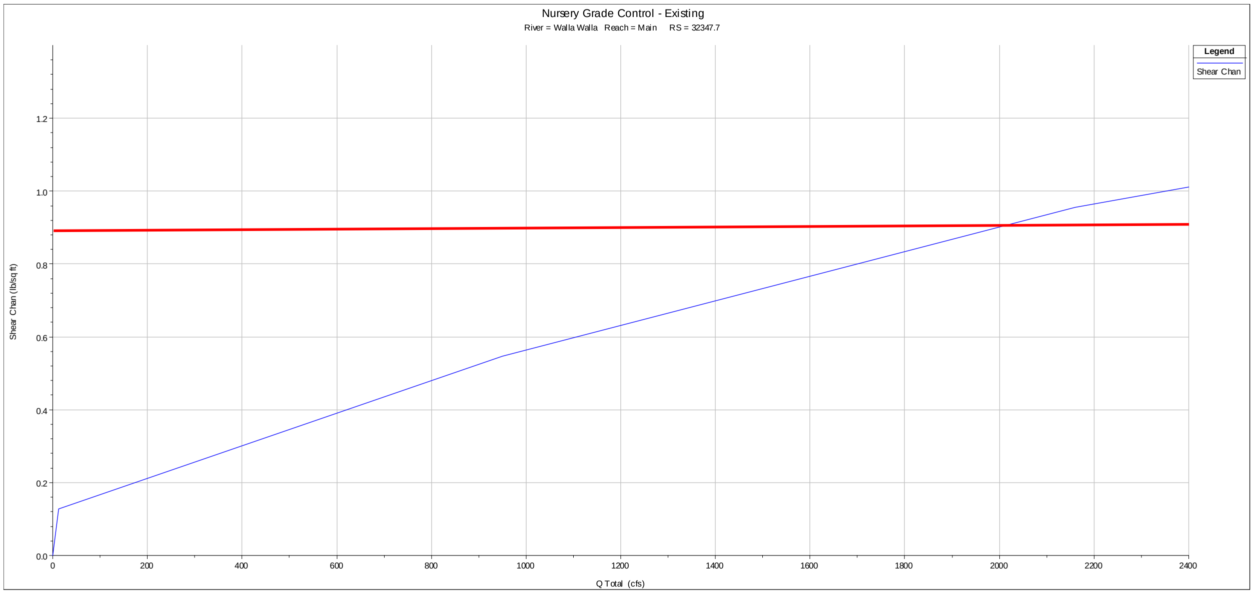
Table 2.6
Minimum Instream Flows

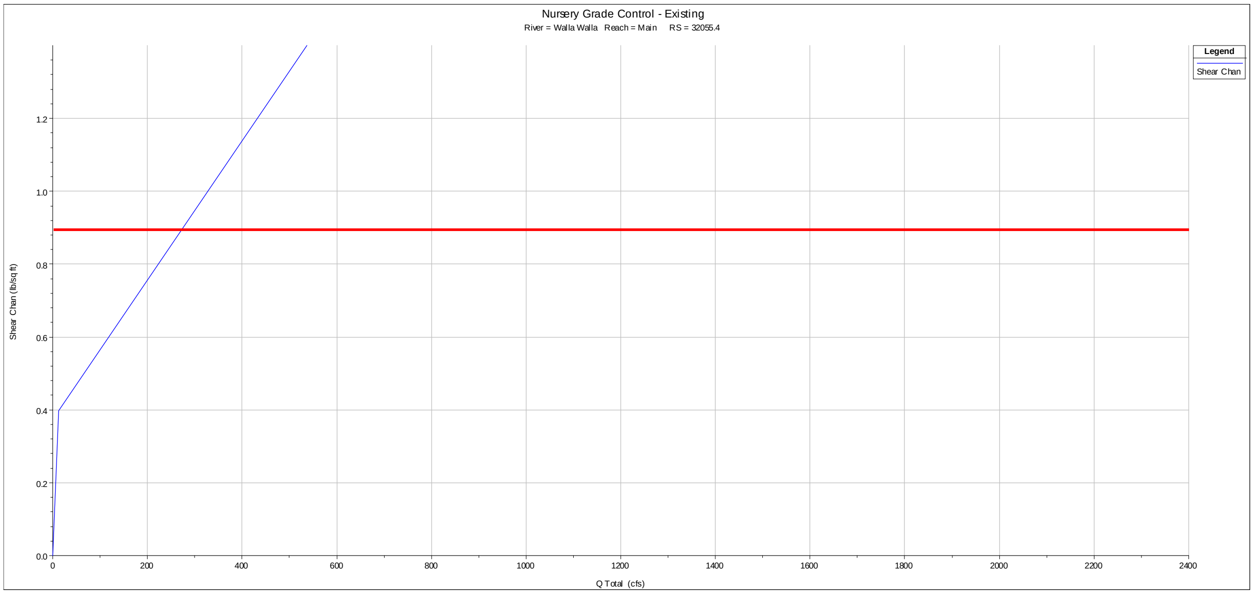
Date	Protected Instream Water (location)	USFWS Agreed @Nursery	Tribe Targets @Nursery
1-Oct	12	13	65
31-Oct	12	13	65
1-Nov	12	13	65
30-Nov	12	13	65
1-Dec	12	13	0
31-Dec	12	13	0
1-Jan	12	15	0
31-Mar	12	15	0
1-Apr	12	15	150
30-Apr	12	15	150
1-May	12	15	150
31-May	12	15	150
1-Jun	12	15	150
15-Jun	12	15	150
16-Jun	12	15	100
30-Jun	12	15	100
1-Jul	12	13	65
31-Jul	12	13	65
1-Aug	12	13	65
31-Aug	12	13	65
1-Sep	12	13	65
30-Sep	12	13	65

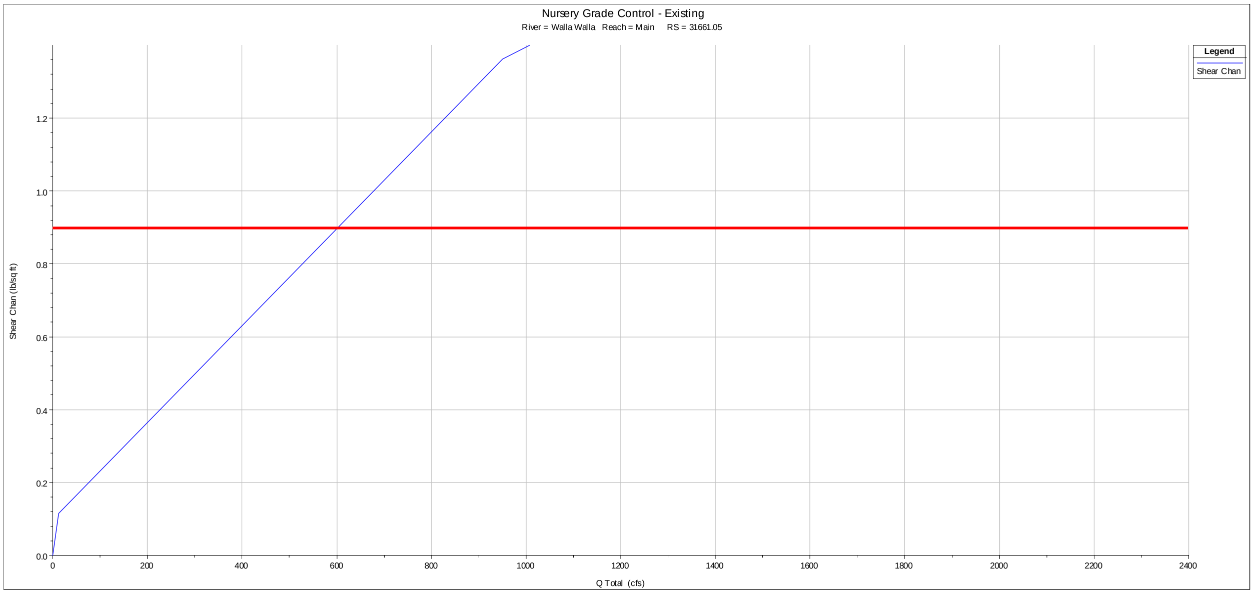
Table 2.7

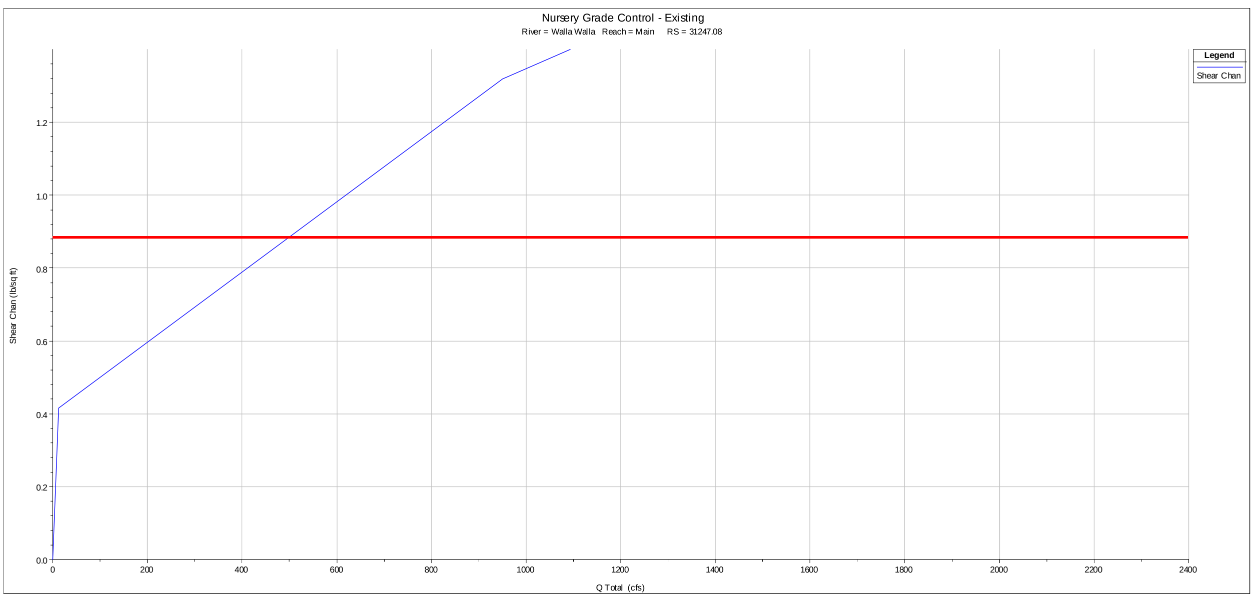
Return Period	**Upstream Historic**	**Downstream Historic**	**30% Diversion**
2	1210	1172	1066
5	1702	1685	1611
10	2033	2026	1971
15	2221	2219	2173
20	2354	2353	2313
25	2457	2456	2420
50	2776	2775	2749
100	3098	3093	3071
200	3425	3411	3389
500	3868	3834	3805

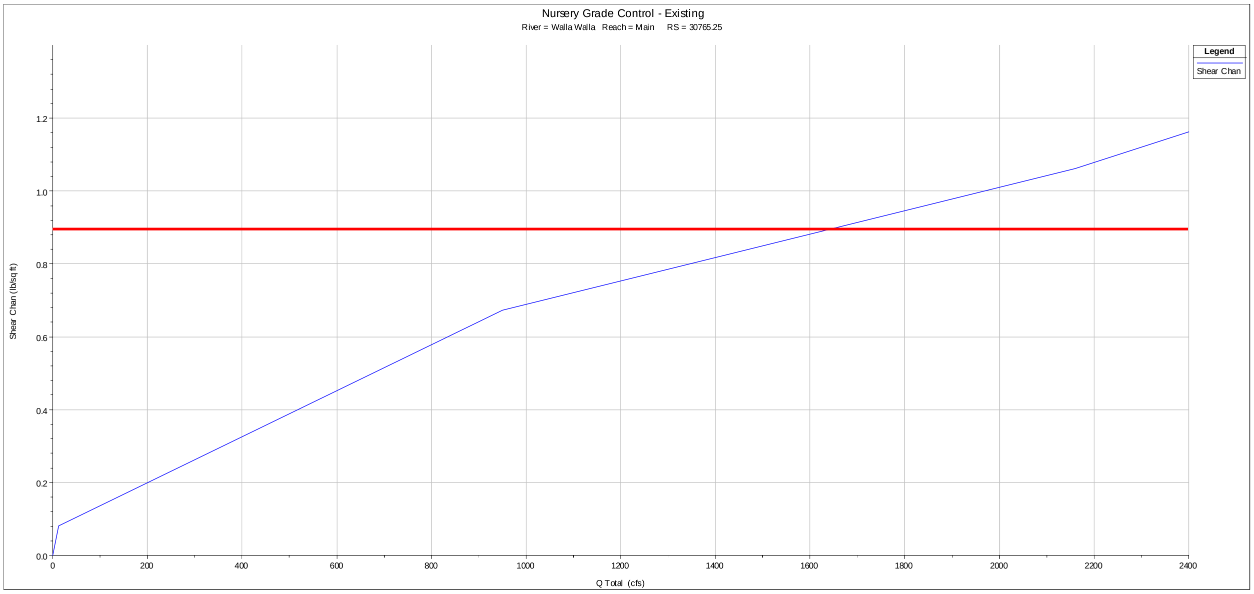
Rating curves of shear stress versus discharge, RS 32347.7 (Cemetery bridge) – 25795 (downstream railroad bridge). Estimated critical shear stress (0.9 psf) shown as red line.



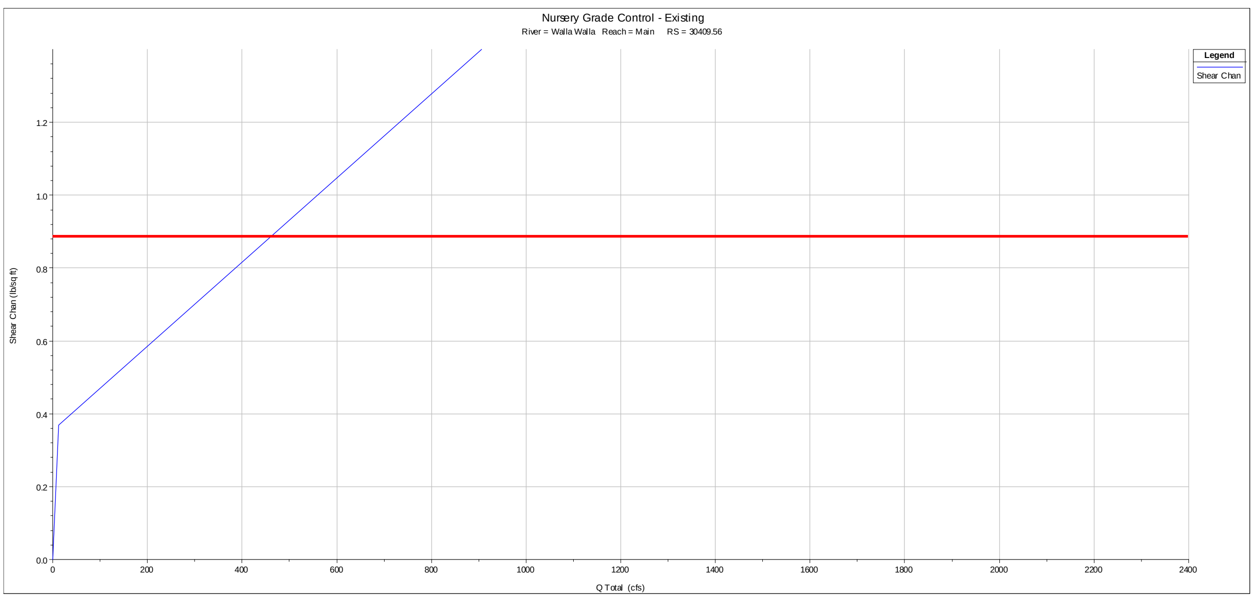



Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 31661.05
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

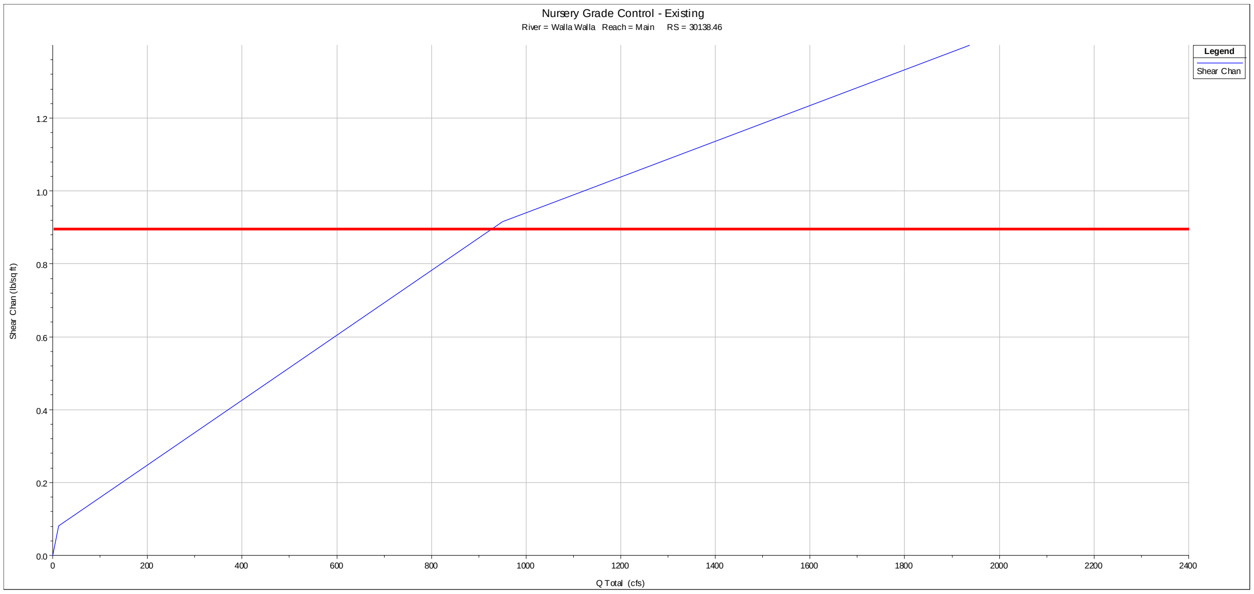

Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 31247.08
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

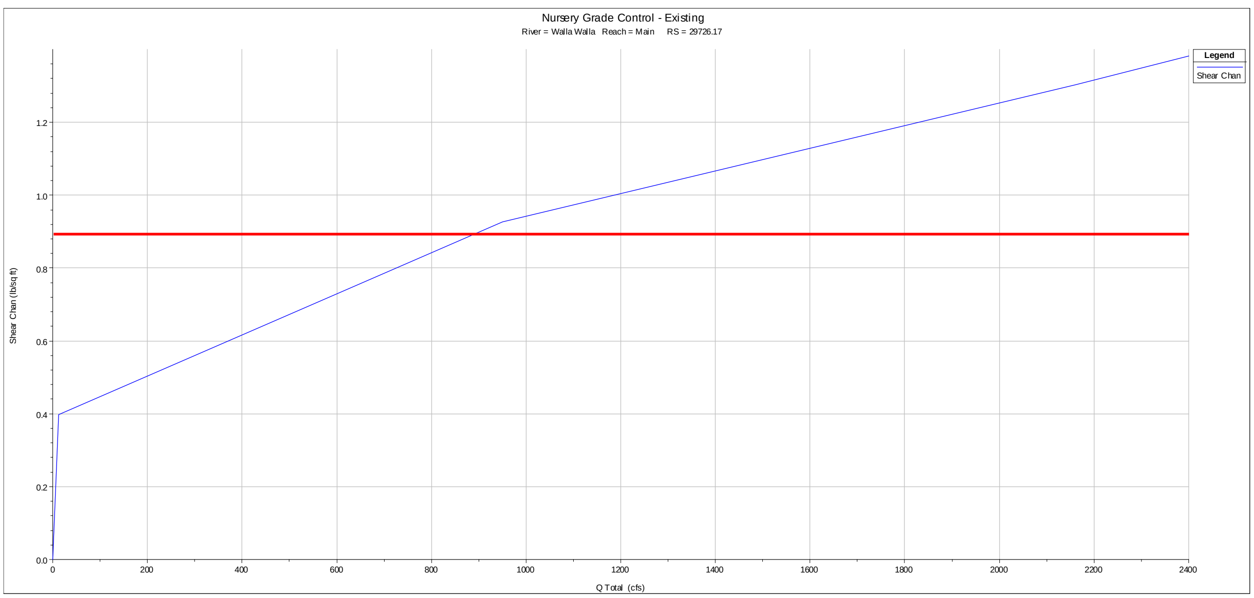


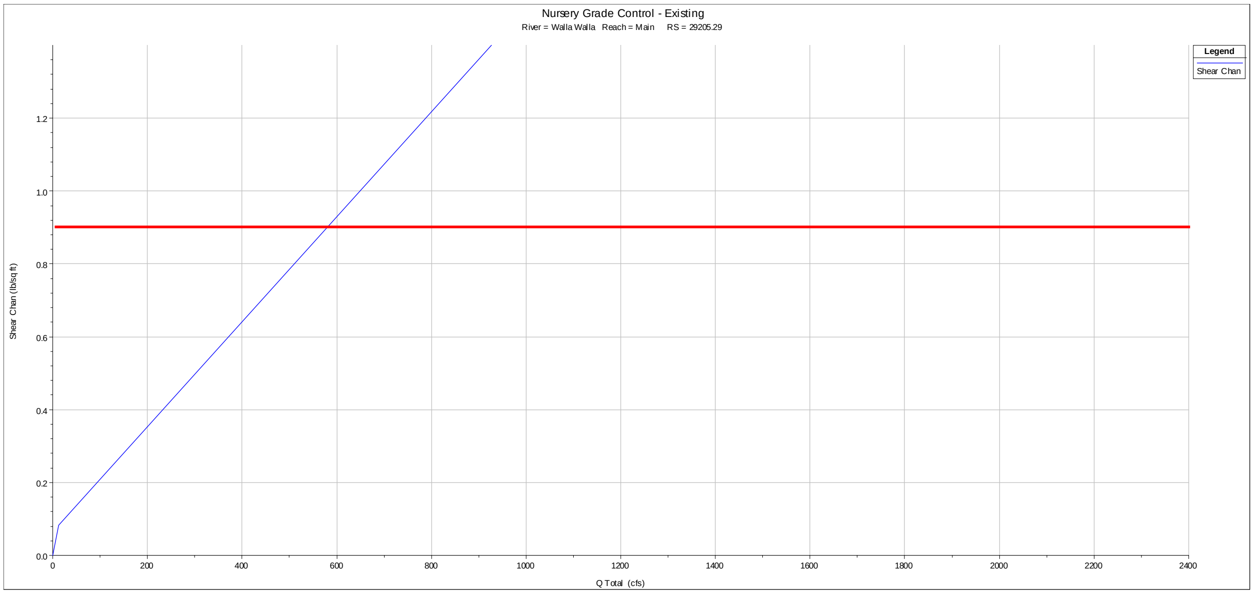
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 30765.25
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)



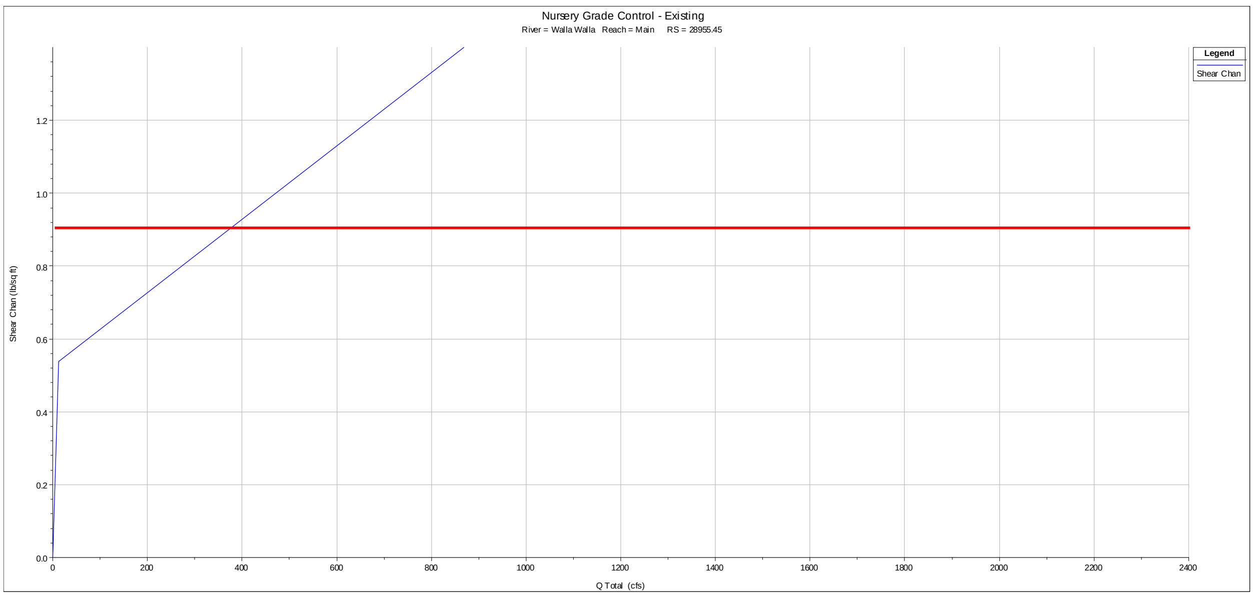
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 30409.56
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 30138.46
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)

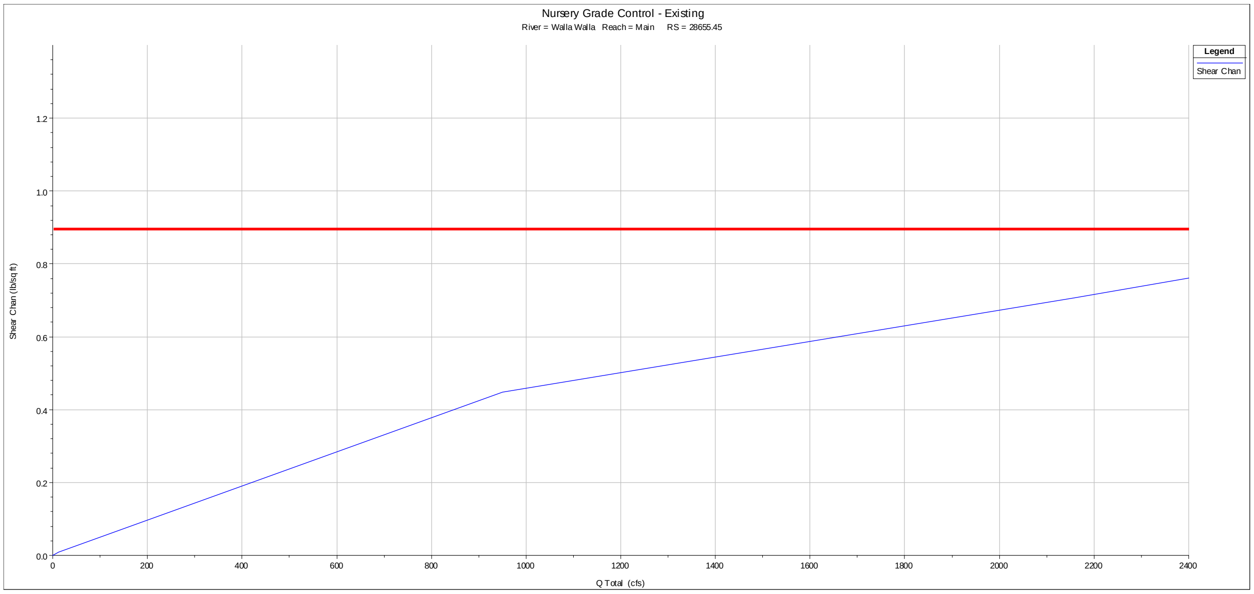

Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 29726.17
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)

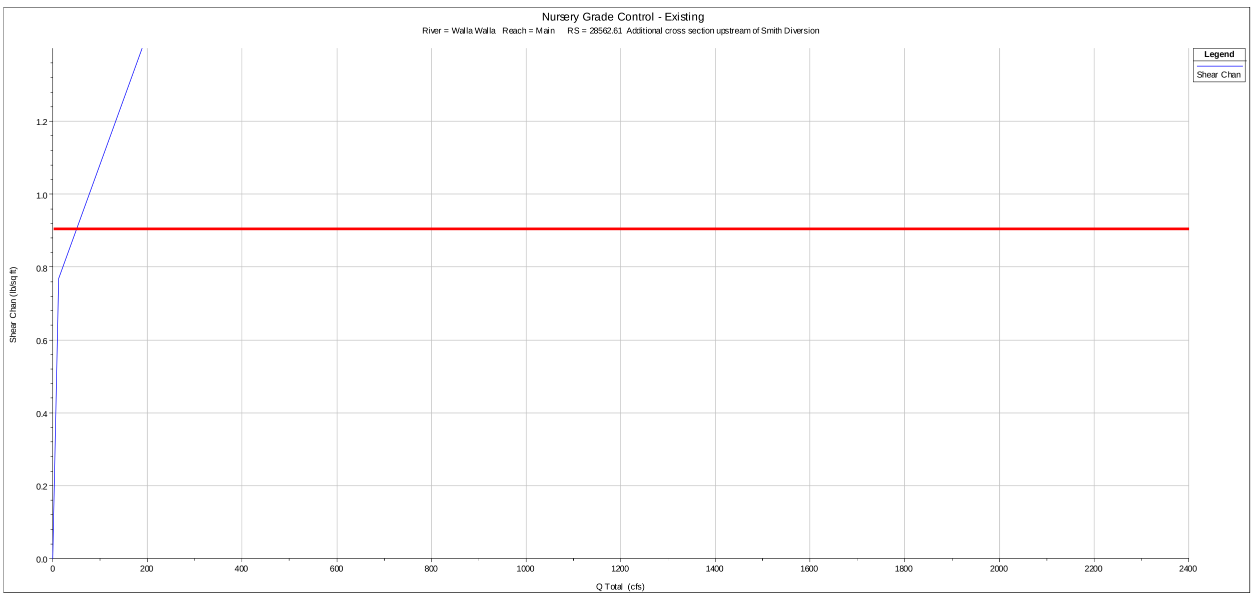


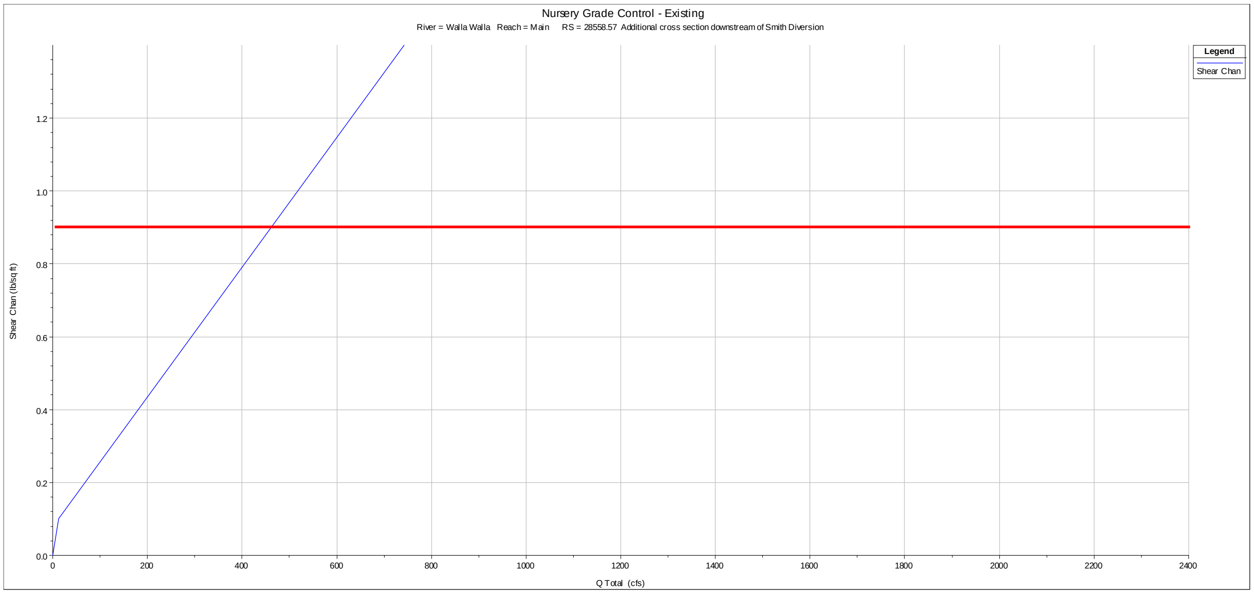
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 29205.29
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400



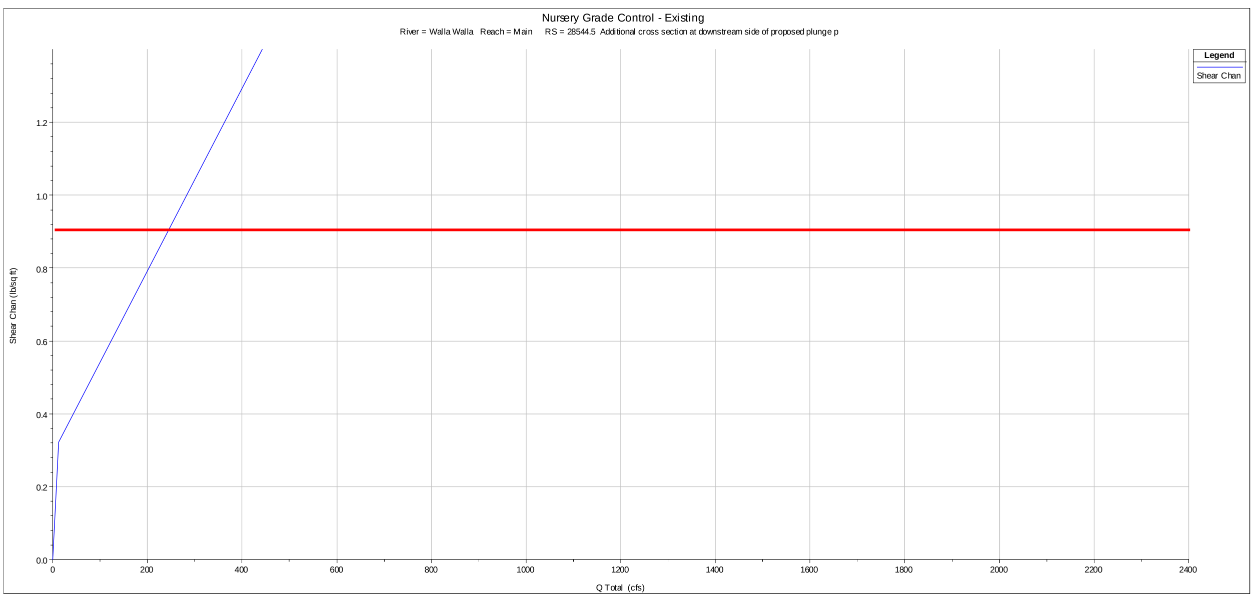
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28955.45
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400


Nursery Grade Control - Existing
River = Walla Walla   Reach = Main   RS = 28655.45
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)

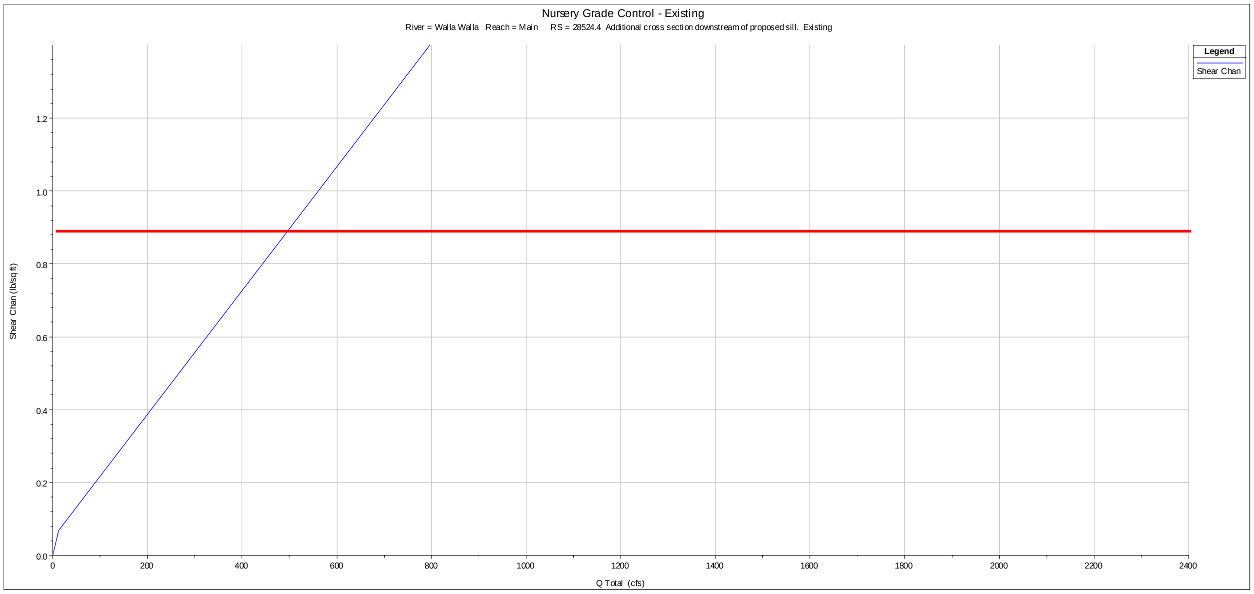

Nursery Grade Control - Existing
River = Walla Walla   Reach = Main   RS = 28562.61 Additional cross section upstream of Smith Diversion
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)

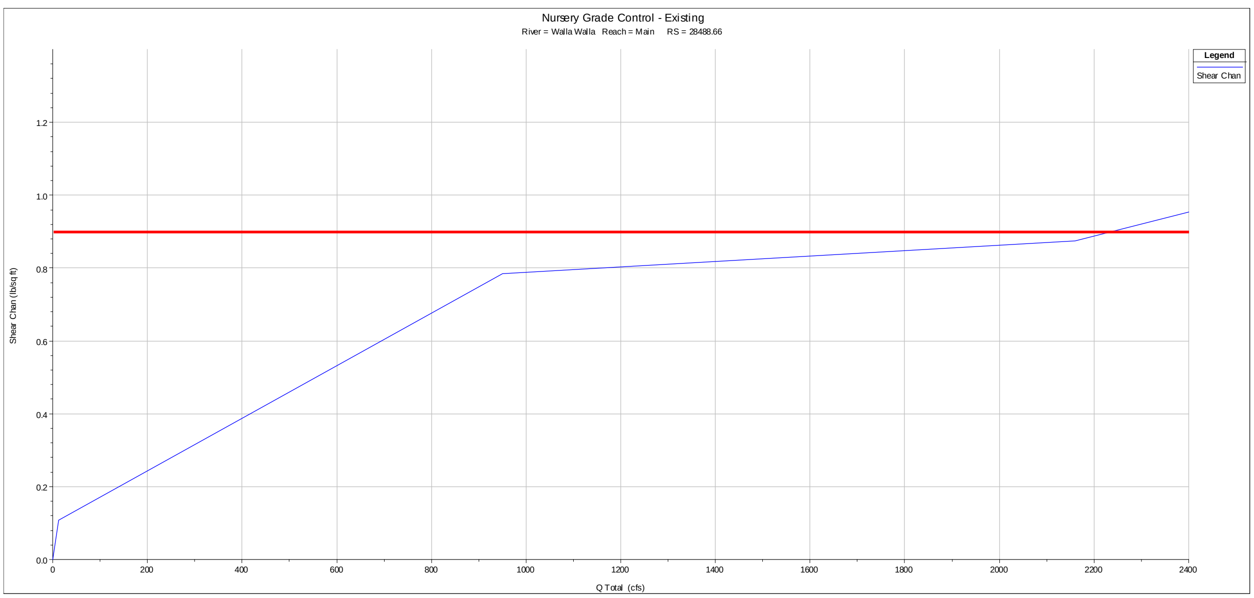


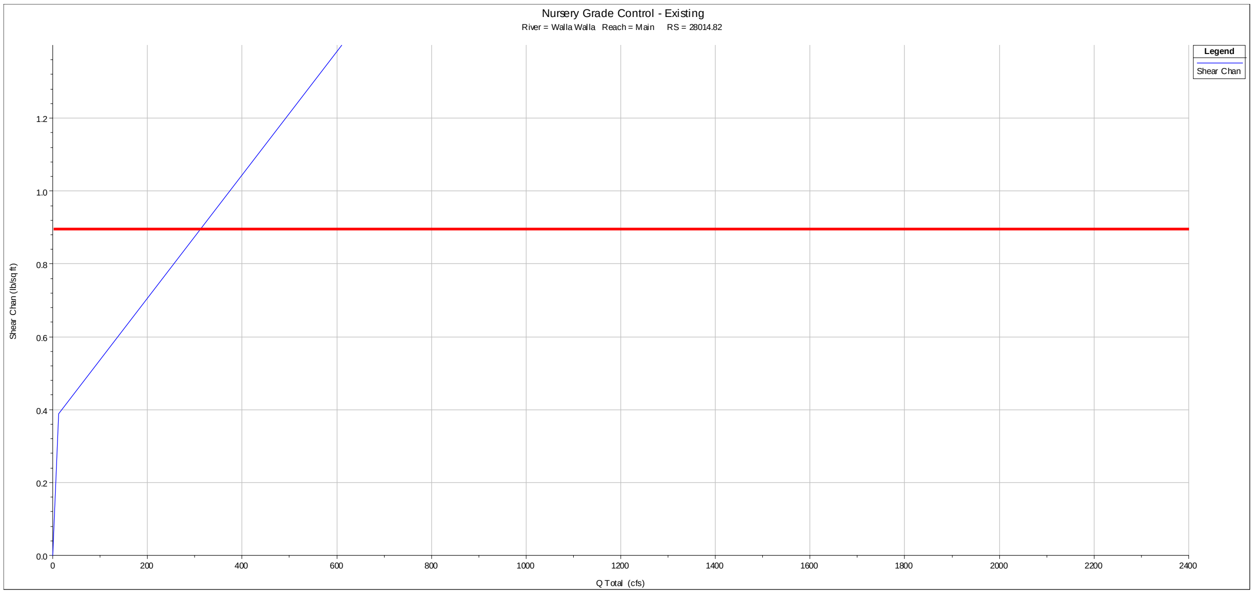
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28558.57 Additional cross section downstream of Smith Diversion
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)



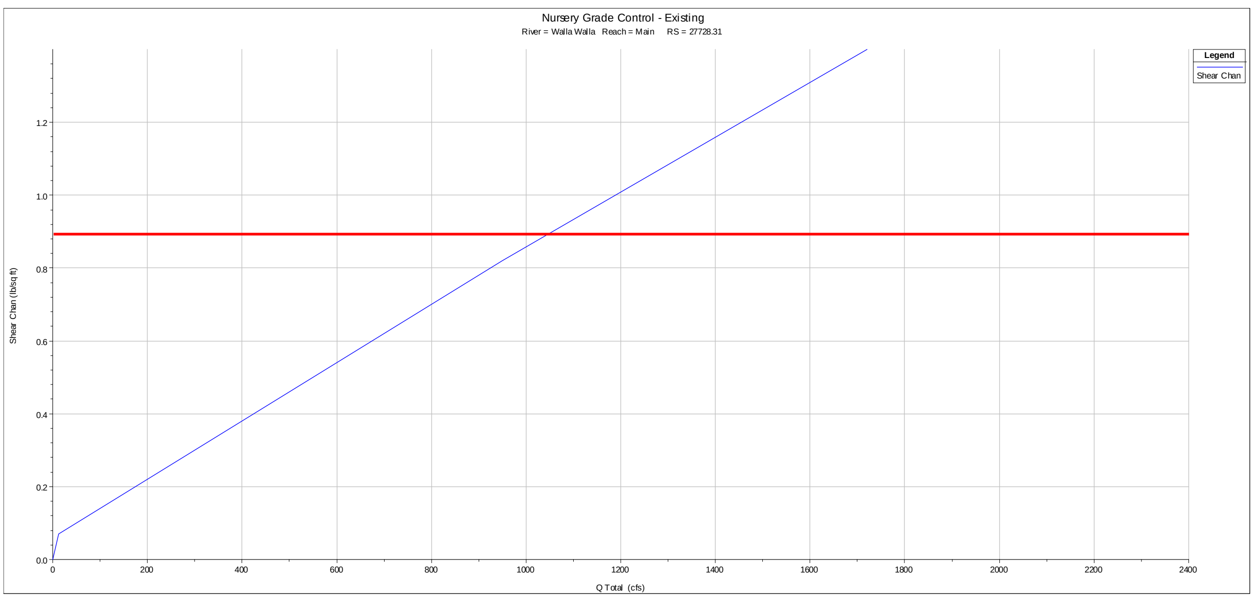
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28544.5 Additional cross section at downstream side of proposed plunge p
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28524.4 Additional cross section downstream of proposed sill. Existing
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)

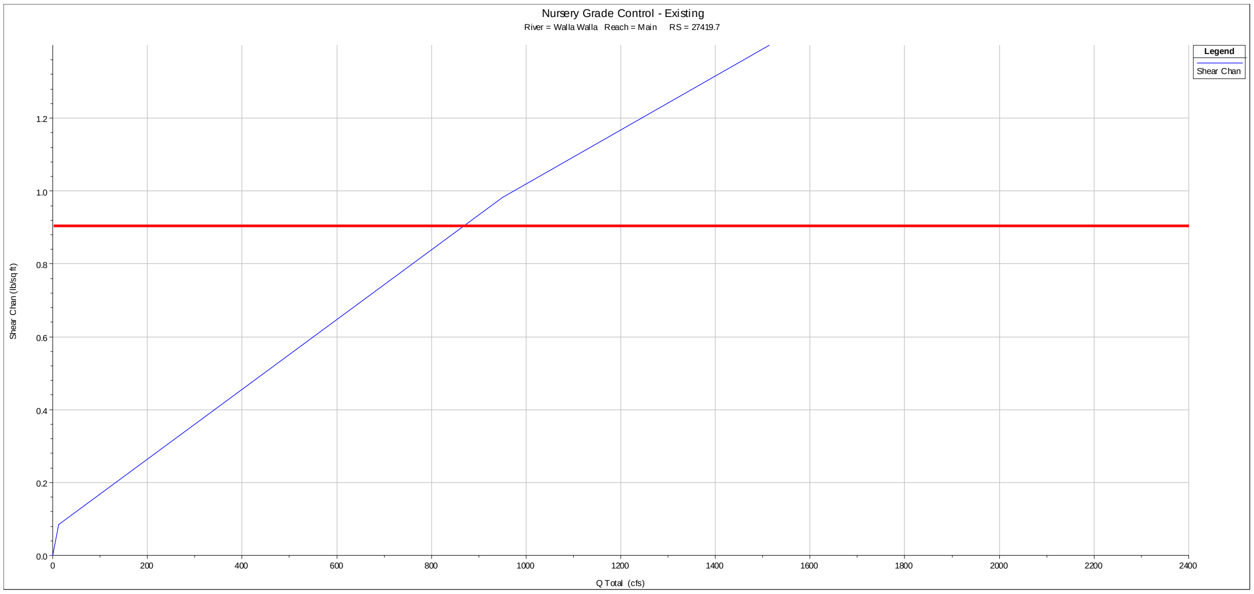

Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28488.66
Legend
Shear Chan
Shear Chan (lb/sq ft)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Q Total (cfs)



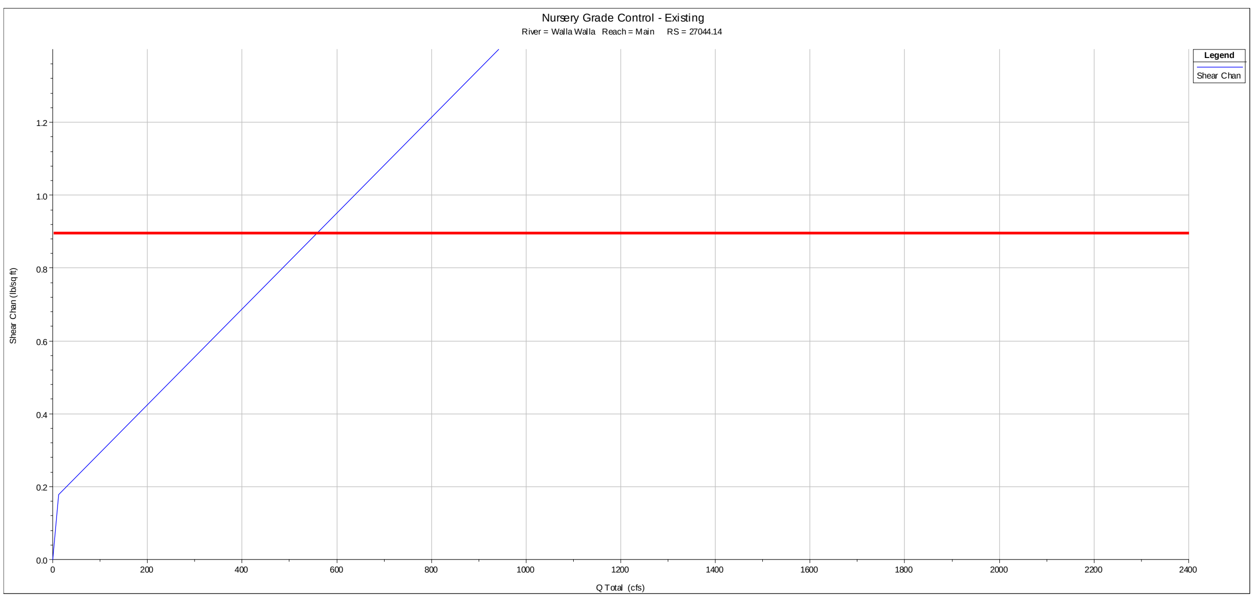
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 28014.82
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)



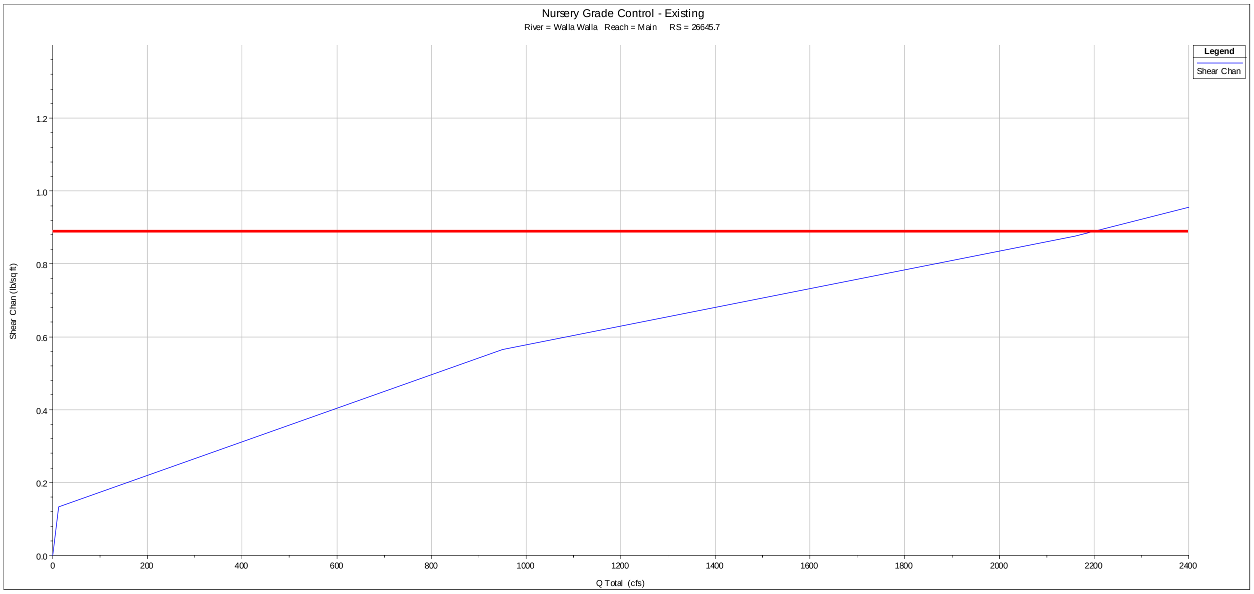
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 27728.31
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)

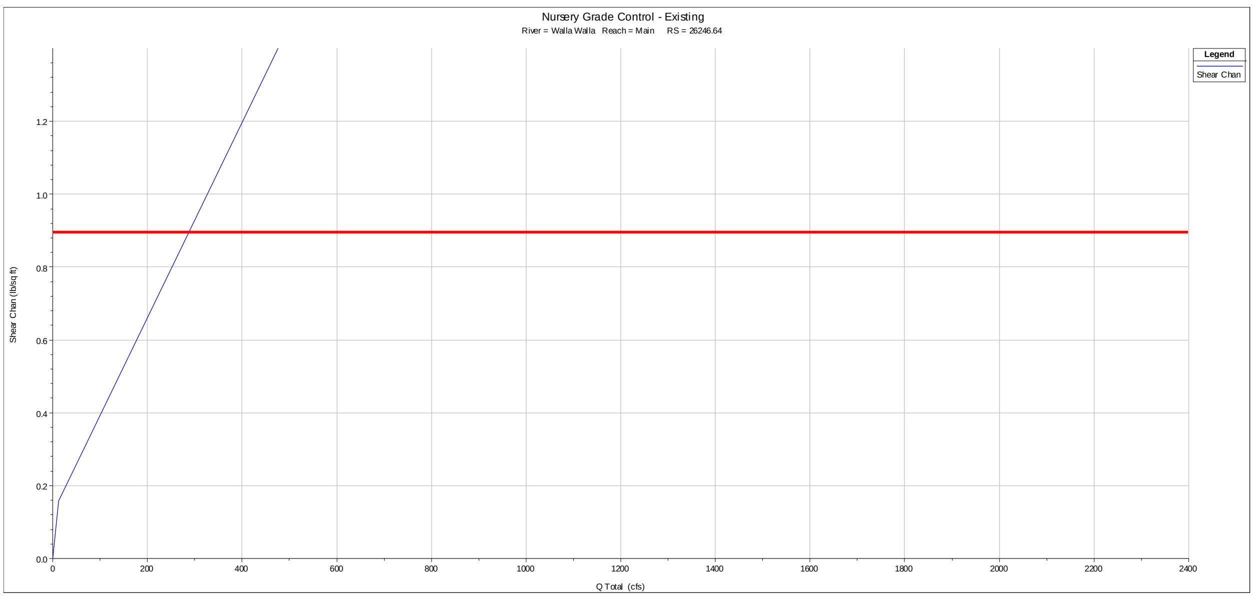


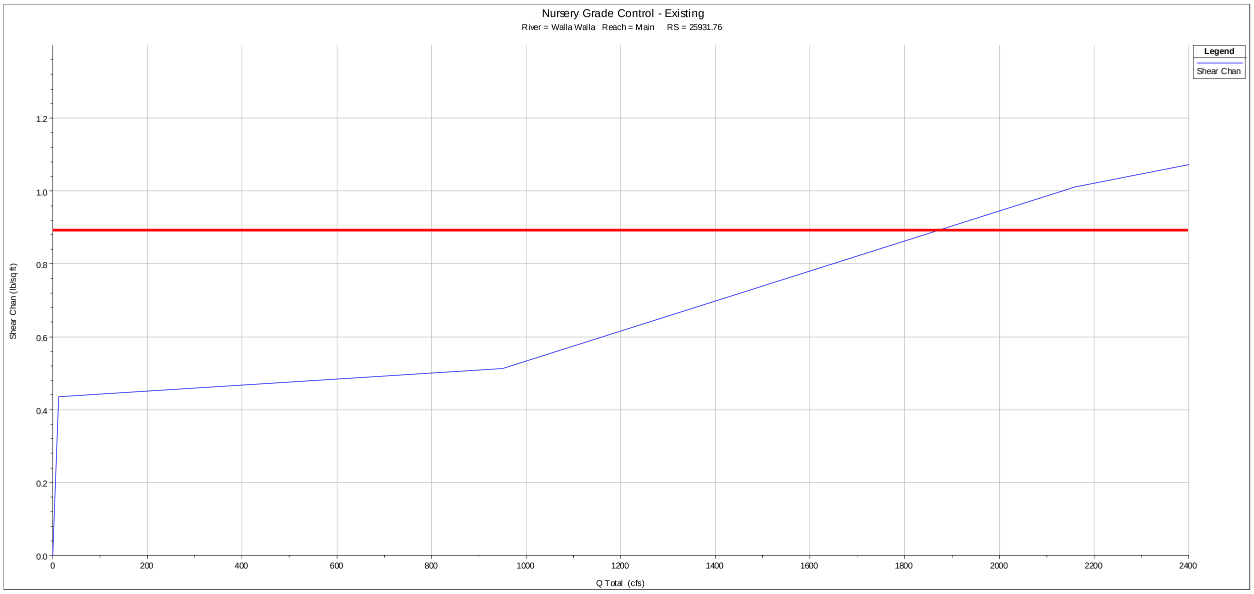
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 27419.7
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

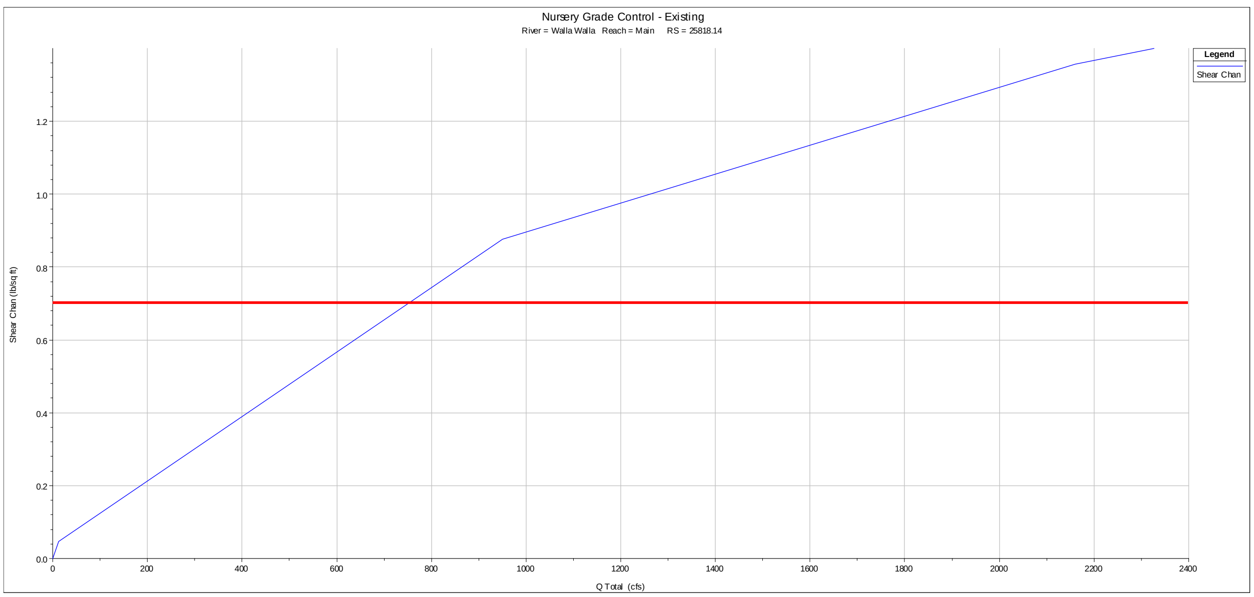


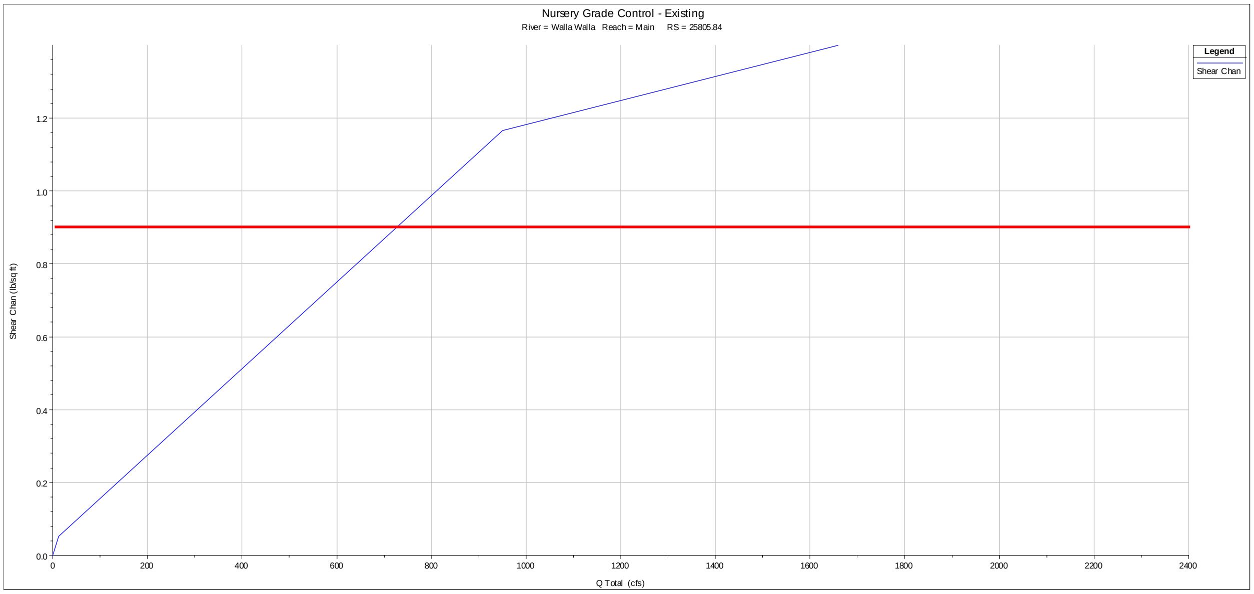
Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 27044.14
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

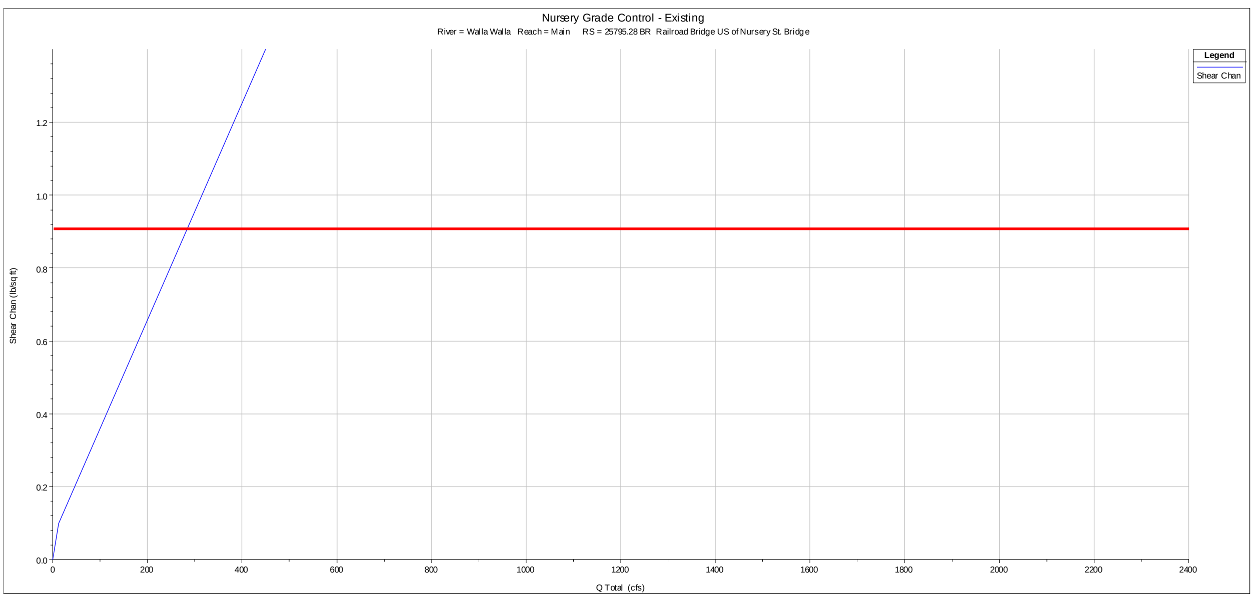

Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 26645.7
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 26246.64
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 25931.76
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 25818.14
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 25805.84
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400


Nursery Grade Control - Existing
River = Walla Walla Reach = Main RS = 25795.28 BR Railroad Bridge US of Nursery St. Bridge
Legend
Shear Chan
Shear Chan (lb/sq ft)
Q Total (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

Appendix D
Cost Estimate

Pine Creek Reservoir - 26,600 AF (small)
Class 4 Construction Cost Estimate
RCC Dam

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
RCC Dam						
						About 12 acre under footprint of dam and downstream channel
	Clearing and Grubbing	22	AC	$ 5,000	$ 110,000	Assume additional 10 acres for access roads, stockpiling, staging, etc..
	Surface Restoration	10	AC	$ 5,000	$ 50,000	Assume 10 acres restoration
	Soil Excavation	334,600	CY	$ 8	$ 2,676,800	
	Rock Excavation	266,600	CY	$ 20	$ 5,332,000	
	Roller Compacted Concrete (RCC)	1,203,200	CY	$ 73	$ 87,833,600	***See Steve Tatro Spreadsheet for Unit Price***
	Gallery	1	LS	$ 500,000	$ 500,000	Allowance
	Ogee Crest	165	LF	$ 3,000	$ 495,000	Unit price for ogee crest based on Duck River Dam cost
	Foundation Drains	6,500	LF	$ 30	$ 195,000	Assume 15 ft drain spacing (1,900 ft and 50 ft long holes; total no. of holes = 130
	Foundation Preparation (cleaning, dental concrete, etc..)	1	LS	$ 1,320,000	$ 1,320,000	Estimate approx 330,000 sq ft; $4 per sq ft
	Geotechnical Instrumentation	1	LS	$ 300,000	$ 300,000	Allowance
				Subtotal	**$ 98,812,400**	
Foundation Grouting						
	Mobilization/Demobilization	1	LS	$ 4,100	$ 4,100	Approximately 5% of Total
						Grouting from Sta 0+00 to Sta 2787+00, i.e., total distance of about 2800 ft; **Curtain Grouting**: - Assume 2-row grout curtain with final average hole spacing of 7.5 feet for total of 700 grout curtain holes, i.e, assume final pattern hole spacing of 10 feet with some areas of tertiary grouting with final hole spacing of 5 ft. - Three hundred and fifty (350) 200-foot average holes over 50% of dam length (total drilling length = 70,000 ft) - Three hundred and fifty (350) 100-ft holes over 50% of dam length (total drilling length = 35,000 ft) **Blanket Grouting:** - Assume 2 rows of blanket grout holes with final hole spacing of 7.5 feet for total of 700 blanket grout holes. - Assume blanket grout hole length = 25 ft
	Drilling	122,500	LF	$ 25	$ 3,062,500	- Total drilling length = 17,500 ft (700 holes x 25/ft/hole)
	Grout Nipples	1,288	EA	$ 100	$ 128,800	Total number of holes = 1,400 (350 + 350 + 700)
						Assume average 16 hookups per hole (200-ft long hole assuming 15-ft stages, plus 2 extra hook-ups per hole) for total of 5,600 hook-ups. Assume average 9 hookups per hole (100-ft long hole assuming 15-ft stages, plus 2 extra hook-ups per hole) for total of 3,150 hook-ups.
	Hookups	9,450	EA	$ 300	$ 2,835,000	Assume 1 hookup for 25-ft long blanket grout holes for total of 700 hook-ups
	Type 3 Cement	122,500	SACKS	$ 15	$ 1,837,500	Assume grout take of 1 sack (94 lbs) per 1 lineal foot
	Microsilica	12,250	SACKS	$ 8	$ 98,000	Assume microsilica content is 10% of cement
	Water Pressure Testing	550	Hrs	$ 160	$ 88,000	Estimated No of hours = 650 hrs
						Assume verification boring every 100 ft along curtain for total of 22 borings
	Verification Borings	3,300	LF	$ 60	$ 198,000	Assume average length of verification boring = 150 ft
				Subtotal	**$ 8,251,900**	
Spillway						
						Estimated training wall surface = 2 x 1250 sq ft
	Training walls - (1379 s.f. 1'-8" thk, x2)	140	CY	$ 700	$ 98,000	Assume 1.5-ft thick walls
						Estimated stilling basin wall surface = 2 x 3012 sq ft
	Stilling basin walls - (3012 s.f. * 2.7' wide (avg) x2)	602	CY	$ 700	$ 421,400	Assume 2.7-ft thick walls
	Stilling Basin Slab	963	CY	$ 480	$ 462,240	About 78 ft x 160 ft in area and 2 ft thick
	Stilling Basin Anchors	70	EA	$ 300	$ 21,000	Assume 70 rock dowels at 10 ft spacing and 15 ft deep
	Stilling Basin Drains	990	LF	$ 30	$ 29,700	Assume 33 drains (15 ft spacing) and 20 ft deep
	Left Retaining Wall (3346 s.f. * 2.7' (avg))	335	CY	$ 700	$ 234,220	
	Right Retaining Wall (6881 s.f. * 2.7' (avg))	688	CY	$ 700	$ 481,670	
	Sill 52.25 * 165' long	319	CY	$ 700	$ 223,514	
				Subtotal	**$ 1,971,744**	
Intake Structure						
	Structural Fill Below Structure	1,800	CY	$ 25	$ 45,000	Assume 40' by 40' by 30 ' deep
	Reinforced Concrete	100	CY	$ 500	$ 50,000	approximately 100 cy
	Trash Rack	1	EA	$ 50,000	$ 50,000	
	Slide Gate including frame and actuator	1	EA	$ 250,000	$ 250,000	
				Subtotal	**$ 395,000**	
Outlet Works						
	Outlet Conduit (78-in Pipe encased in concrete)	240	LF	$ 1,350	$ 324,000	
	Low Flow - 24" Ball, Plunger Valve, Flow Meter	1	EA	$ 314,000	$ 314,000	Pratt rubber seated BV and VAG plunger installed
	Emergency Release - 30" Cone Valve and 60" BFV	1	EA	$ 365,000	$ 365,000	Vanessa
	78" Isolation Valve (Butterfly Valve)	1	EA	$ 280,000	$ 280,000	150 psi AWWA C504
	Piping and fittings	1	EA	$ 150,000	$ 150,000	
	Vault Structural	1	EA	$ 85,000	$ 85,000	
				Subtotal	**$ 1,518,000**	
Diversion and Control of Water						
	Cofferdam/Diversion of Creek/Water control	1	LS	$ 1,500,000	$ 1,500,000	Allowance
				Subtotal	**$ 1,500,000**	
Totals						
				Subtotal	**$ 112,449,044**	
	Contingency including Miscellaneous Items (20%)				$ 22,489,800	
				Total Raw Cost	**$ 134,938,844**	
	Jobsite Overhead (Contractor Indirects)			7.00%	$ 9,445,719	Include Mobilization, Demobilization, Superintendent, Vehicles, Minor Traffic Control, SWPPP, Safety, Job Site Storage, Trailers, ect.
	Subtotal - Contractor Direct Cost				**$ 144,384,563**	
	Home Office Overhead (Prime Contractor CM / Overhead)			10.00%	$ 14,438,456	
	Prime Contractor Profit			5.00%	$ 7,219,228	
	Prime Contractor Bond / Insurance			2.50%	$ 3,609,614	
	Subtotal – Contract Cost				**$ 169,651,861**	
	Owner's Contingency			5.00%	$ 8,482,593	
	Design			6.00%	$ 10,179,112	
	Construction Management and Inspection			7.00%	$ 11,875,630	
	Lands and Damages				$ 1,200,000	
	Total Facility Cost				**$ 201,389,000**	

Pine Creek Reservoir - 39,300 AF (large)
Class 4 Construction Cost Estimate
RCC Dam

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
RCC Dam						
	Clearing and Grubbing	13	AC	$ 5,000	$ 65,000	About 13 acre under footprint of dam and downstream channel Assume additional 10 acres for access roads, stockpiling, staging, etc..
	Surface Restoration	10	AC	$ 5,000	$ 50,000	Assume 10 acres restoration
	Soil Excavation	363,100	CY	$ 8	$ 2,904,800	
	Rock Excavation	294,500	CY	$ 20	$ 5,890,000	
	Roller Compacted Concrete (RCC)	1,477,200	CY	$ 73	$ 107,835,600	***See Steve Tatro Spreadsheet for Unit Price***
	Gallery	1	LS	$ 500,000	$ 500,000	Allowance
	Ogee Crest	165	LF	$ 3,000	$ 495,000	Unit price for ogee crest based on Duck River Dam cost
	Foundation Drains	7,000	LF	$ 30	$ 210,000	Assume 15 ft drain spacing (2,100 ft from Sta 3+00 to Sta 24+00) and 50 ft long holes;
	Foundation Preparation (cleaning, dental concrete, etc..)	1	LS	$ 1,520,000	$ 1,520,000	Estimate approx 380,000 sq ft; $4 per sq ft
	Geotechnical Instrumentation	1	LS	$ 300,000	$ 300,000	Allowance
				Subtotal	**$ 119,770,400**	
Foundation Grouting						
	Mobilization/Demobilization	1	LS	$ 450,000	$ 450,000	Approximately 5% of Total
	Drilling	130,875	LF	$ 25	$ 3,271,875	Grouting from Sta 0+00 to Sta 2787+00, i.e., total distance of about 2800 ft; **Curtain Grouting**: - Assume 2-row grout curtain with final average hole spacing of 7.5 feet for total of 748 grout curtain holes, i.e, assume final pattern hole spacing of 10 feet with some areas of tertiary grouting with final hole spacing of 5 ft. - Three hundred and seventy four (374) 200-foot average holes over 50% of dam length (total drilling length = 74,800 ft) - Three hundred and seventy four (374) 100-ft holes over 50% of dam length (total drilling length = 37,400 ft) **Blanket Grouting:** - Assume 2 rows of blanket grout holes with final hole spacing of 7.5 feet for total of 747 blanket grout holes. - Assume blanket grout hole length = 25 ft - Total drilling length = 18,675 ft (747 holes x 25/ft/hole)
	Grout Nipples	1,288	EA	$ 100	$ 128,800	Total number of holes = 1,495 (374 + 374 + 747)
	Hookups	10,097	EA	$ 300	$ 3,029,100	Assume average 16 hookups per hole (200-ft long hole assuming 15-ft stages, plus 2 extra hook-ups per hole) for total of 5984 hook-ups. Assume average 9 hookups per hole (100-ft long hole assuming 15-ft stages, plus 2 extra hook-ups per hole) for total of 3366 hook-ups. Assume 1 hookup for 25-ft long blanket grout holes for total of 747 hook-ups
	Type 3 Cement	130,875	SACKS	$ 15	$ 1,963,125	Assume grout take of 1 sack (94 lbs) per 1 lineal foot
	Microsilica	13,088	SACKS	$ 8	$ 104,704	Assume microsilica content is 10% of cement
	Water Pressure Testing	600	Hrs	$ 160	$ 96,000	Estimated No of hours = 600 hrs
	Verification Borings	4,200	LF	$ 60	$ 252,000	Assume verification boring every 100 ft along curtain for total of 28 borings Assume average length of verification boring = 150 ft
				Subtotal	**$ 9,295,604**	
Spillway						
	Training walls - (1379 s.f. 1'-8" thk, x2)	170	CY	$ 700	$ 119,000	Estimated training wall surface = 2 x 1379 sq ft Assume 1.5-ft thick walls
	Stilling basin walls - (3012 s.f. * 2.7' wide (avg) x2)	602	CY	$ 700	$ 421,400	Estimated stilling basin wall surface = 2 x 3012 sq ft Assume 2.7-ft thick walls
	Stilling Basin Slab	963	CY	$ 480	$ 462,240	About 78 ft x 160 ft in area and 2 ft thick
	Stilling Basin Anchors	70	EA	$ 300	$ 21,000	Assume 70 rock dowels at 10 ft spacing and 15 ft deep
	Stilling Basin Drains	990	LF	$ 30	$ 29,700	Assume 33 drains (15 ft spacing) and 20 ft deep
	Left Retaining Wall (3346 s.f. * 2.7' (avg))	335	CY	$ 700	$ 234,220	
	Right Retaining Wall (6881 s.f. * 2.7' (avg))	688	CY	$ 700	$ 481,670	
	Sill 52.25 * 165' long	319	CY	$ 700	$ 223,514	
				Subtotal	**$ 1,992,744**	
Intake Structure						
	Structural Fill Below Structure	1,800	CY	$ 25	$ 45,000	Assume 40' by 40' by 30 ' deep
	Reinforced Concrete	100	CY	$ 500	$ 50,000	approximately 100 cy
	Trash Rack	1	EA	$ 50,000	$ 50,000	SST
	Slide Gate including frame and actuator	1	EA	$ 250,000	$ 250,000	VAG (Rodney Hunt)
				Subtotal	**$ 395,000**	
Outlet Works						
	Outlet Conduit (78-in Pipe encased in concrete)	100	LF	$ 1,350	$ 135,000	
	Low Flow - 24" Ball, Plunger Valve, Flow Meter	1	EA	$ 314,000	$ 314,000	Pratt rubber seated BV and VAG plunger installed
	Emergency Release - 30" Cone Valve and 60" BFV	1	EA	$ 365,000	$ 365,000	Vanessa
	78" Isolation Valve (Butterfly Valve)	1	EA	$ 280,000	$ 280,000	150 psi AWWA C504
	Piping and fittings	1	EA	$ 150,000	$ 150,000	
	Vault Structural	1	EA	$ 85,000	$ 85,000	
				Subtotal	**$ 1,329,000**	
Diversion and Control of Water						
	Cofferdam/Diversion of Creek/Water control	1	LS	$ 1,500,000	$ 1,500,000	Allowance
				Subtotal	**$ 1,500,000**	
Totals						
				Subtotal	**$ 134,282,748**	
	Contingency including Miscellaneous Items (20%)				$ 26,856,550	
				Total Raw Cost	**$ 161,139,298**	
	Jobsite Overhead (Contractor Indirects)			7.00%	$ 11,279,751	Include Mobilization, Demobilization, Superintendent, Vehicles, Minor Traffic Control, SWPPP, Safety, Job Site Storage, Trailers, etc..
				Subtotal - Contractor Direct Cost	**$ 172,419,049**	
	Home Office Overhead (Prime Contractor CM / Overhead)			10.00%	$ 17,241,905	
	Prime Contractor Profit			5.00%	$ 8,620,952	
	Prime Contractor Bond / Insurance			2.50%	$ 4,310,476	
				Subtotal – Contract Cost	**$ 202,592,382**	
	Owner's Contingency			5.00%	$ 10,129,619	
	Design			6.00%	$ 12,155,543	
	Construction Management and Inspection			7.00%	$ 14,181,467	
	Lands and Damages				$ 1,200,000	
				Total Facility Cost	**$ 240,259,000**	

 Printed on 9/14/2017

Pine Creek Reservoir
Class 4 Construction Cost Estimate
Main Conveyance Pipeline

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 1,640,000	$ 1,640,000	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 2,050,000	$ 2,050,000	Approximately 5% of Total
	Cathodic Protection & Testing	1	LS	$ 370,000	$ 370,000	Allowance
	FO Conduit, Pull Box, Cable, Testing	43500	LF	$ 6	$ 261,000	Allowance
	Ground Restoration, Seed & Plant	43500	LF	$ 5	$ 217,500	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 50,000	$ 50,000	Allowance
				Subtotal	**$ 4,588,500**	
Main Pipeline						
	78" WSP Fabrication	46220	LF	$ 624	$ 28,841,280	Excludes portion on bridge but includes portion in tunnel
	78" Install - Levee	7105	LF	$ 234	$ 1,662,570	maintain 15' clear space from levee drainage ditch
	78" Install - City	3900	LF	$ 706	$ 2,753,010	mostly in streets & under sewer (STA 355+45 to 394+45)
	78" Install - Rural	35215	LF	$ 234	$ 8,240,310	(STA 3+30 to 355+45)
				Subtotal	**$ 41,497,170**	
Appurtenances and Misc Conveyance Structures						
	River Diversion Modification	1	LS	$ 556,400	$ 556,400	USACE price allowance with escalation
	River Diversion Expansion	1	LS	$ 445,120	$ 445,120	added 40 cfs redundancy and sediment trap back to river
	Oversize Blowoff at Dry Creek	1	LS	$ 175,000	$ 175,000	USACE price allowance
				Subtotal	**$ 1,176,520**	
Totals						
				Subtotal	**$ 47,262,190**	
		12%	Design and Admin		$ 5,671,460	
		25%	Contingency		$ 11,815,550	
				Subtotal	**$ 64,749,200**	
			Total Facility Cost		**$ 64,749,000**	

Pine Creek Reservoir

Class 4 Construction Cost Estimate

Irrigation Distribution Pipeline (without Bennington)

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 36,699	$ 36,699	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 45,873	$ 45,873	Approximately 5% of Total
	Electrical Drops to Turnouts	1	LS	$ 350,000	$ 350,000	Allowance
	FO Conduit, Pull Box, Cable, Testing	9882	LF	$ 6	$ 59,292	Allowance
	Ground Restoration, Seed & Plant	9882	LF	$ 5	$ 49,410	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 20,000	$ 20,000	Allowance
				Subtotal	**$ 561,274**	
940 Distribution Pipeline						
	Fab. 32" DR 32.5 (64 psi) HDPE	1354	LF	$ 55	$ 73,928	
	Fab. 26" DR 32.5 (64 psi) HDPE	3726	LF	$ 36	$ 135,626	
	Fab. 22" DR 32.5 (64 psi) HDPE	3115	LF	$ 26	$ 80,990	
	Fab. 18" DR 32.5 (64 psi) HDPE	622	LF	$ 17	$ 10,754	
	Fab. 18" DR 32.5 (64 psi) HDPE	1065	LF	$ 17	$ 18,414	
	Install 32" HDPE	1354	LF	$ 80	$ 108,320	farmland, rural roads, irrigation ROW, at min depth
	Install 26" HDPE	3726	LF	$ 65	$ 242,190	farmland, rural roads, irrigation ROW, at min depth
	Install 22" HDPE	3115	LF	$ 55	$ 171,325	farmland, rural roads, irrigation ROW, at min depth
	Install 18" HDPE	622	LF	$ 45	$ 27,990	farmland, rural roads, irrigation ROW, at min depth
	Install 18" HDPE	1065	LF	$ 45	$ 47,925	farmland, rural roads, irrigation ROW, at min depth
				Subtotal	**$ 917,463**	
Appurtenances and Misc Conveyance Structures						
	940 Turnouts - 2 to 14 cfs	6	LS	$ 235,000	$ 1,410,000	metered, plunger valve, remote flow control in vault
	FROG Turnout - 17 cfs	1	LS	$ 340,000	$ 340,000	metered, plunger valve, remote flow control in vault
	Duff Weir Turnout - 56 cfs	1	LS	$ 450,000	$ 450,000	metered, plunger valve, remote flow control in vault
	Barrett Turnout - 12 cfs	1	LS	$ 300,000	$ 300,000	metered, plunger valve, remote flow control in vault
	Booster Pump Sta to FROG-17 cfs	1	LS	$ 2,200,000	$ 2,200,000	TDH~50', no buildings, adjust 21 cfs Eagle Mountain
				Subtotal	**$ 4,700,000**	
Totals						
				Subtotal	**$ 6,178,737**	
		12%		Design and Admin	$ 741,450	
		25%		Contingency	$ 1,544,680	

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
				Subtotal	$ **8,464,867**	
				Total Facility Cost	**$ 8,465,000**	

Pine Creek Reservoir
Class 4 Construction Cost Estimate
Bennington Conveyance Pipeline

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 680,000	$ 680,000	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 1,700,000	$ 1,700,000	Approximately 10% of Total
	FO Conduit, Pull Box, Cable, Testing	65500	LF	$ 6	$ 393,000	Allowance
	Ground Restoration, Seed & Plant	65500	LF	$ 5	$ 327,500	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 100,000	$ 100,000	Allowance
				Subtotal	**$ 3,200,500**	
Main Pipeline						
	Fab. 36" DR 17 HDPE (140 psi working)	65500	LF	$ 120	$ 7,860,000	
	Install 36" HDPE	65500	LF	$ 90	$ 5,895,000	Open farmland, 3' cover, no rock, no groundwater
				Subtotal	**$ 13,755,000**	
Appurtenances and Misc Conveyance Structures						
	Open Cut Walla Walla River Xing	1	LS	$ 200,000	$ 200,000	Water control, temporary diversion facilities
	Oversize blowoff at Walla Walla River	1	LS	$ 125,000	$ 125,000	USACE price allowance
				Subtotal	**$ 325,000**	
Totals						
				Subtotal	**$ 17,280,500**	
		12%		Design and Admin	$ 2,073,660	
		25%		Contingency	$ 4,320,130	
				Subtotal	**$ 23,674,290**	
				Total Facility Cost	**$ 23,674,000**	

Pine Creek Reservoir
Class 4 Construction Cost Estimate
Lowden Conveyance Pipeline

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 200,000	$ 200,000	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 500,000	$ 500,000	Approximately 10% of Total
	FO Conduit, Pull Box, Cable, Testing	27500	LF	$ 6	$ 165,000	Allowance
	Ground Restoration, Seed & Plant	27500	LF	$ 5	$ 137,500	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 50,000	$ 50,000	Allowance
				Subtotal	**$ 1,052,500**	
Main Pipeline						
	Fab. 36" DR 32.5 HDPE (64 psi)	27500	LF	$ 62	$ 1,705,000	
	Install 36" HDPE	27500	LF	$ 90	$ 2,475,000	Open farmland, 3' cover, no rock, no groundwater
				Subtotal	**$ 4,180,000**	
Appurtenances and Misc Conveyance Structures						
	Diversion structure	1	LS	$ 150,000	$ 150,000	
				Subtotal	**$ 150,000**	
Totals						
				Subtotal	**$ 5,382,500**	
		12%	Design and Admin		$ 645,900	
		25%	Contingency		$ 1,345,630	
				Subtotal	**$ 7,374,030**	
			Total Facility Cost		**$ 7,374,000**	

Pine Creek Reservoir
Class 4 Construction Cost Estimate
Dry Creek Conveyance Pipeline

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 92,000	$ 92,000	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 230,000	$ 230,000	Approximately 10% of Total
	FO Conduit, Pull Box, Cable, Testing	14400	LF	$ 6	$ 86,400	Allowance
	Ground Restoration, Seed & Plant	14400	LF	$ 5	$ 72,000	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 50,000	$ 50,000	Allowance
				Subtotal	**$ 530,400**	
Main Pipeline						
	Fab. 18" DR 32.5 HDPE (64 psi)	14400	LF	$ 17	$ 244,800	
	Install 18" HDPE	14400	LF	$ 45	$ 648,000	Open farmland, 3' cover, no rock, no groundwater
				Subtotal	**$ 892,800**	
Appurtenances and Misc Conveyance Structures						
	Creek diversion and fish screen	1	LS	$ 180,400	$ 180,400	
	Isolation valves	1	LS	$ 100,000	$ 100,000	
				Subtotal	**$ 280,400**	
Totals						
				Subtotal	**$ 1,703,600**	
		12%	Design and Admin		$ 204,430	
		25%	Contingency		$ 425,900	
				Subtotal	**$ 2,333,930**	
			Total Facility Cost		**$ 2,334,000**	

Pine Creek Reservoir
Class 4 Construction Cost Estimate
Upstream River Diversion

Facility	Description	Qty	Unit	Unit Price	Extended Total	Comments
General						
	Mobilization / Demobilization & Cleanup	1	LS	$ 1,160,000	$ 1,160,000	Approximately 4% of Total
	Appurtenances (AV/BO/MW)	1	LS	$ 1,450,000	$ 1,450,000	Approximately 5% of Total
	Cathodic Protection & Testing	1	LS	$ 300,000	$ 300,000	Allowance
	FO Conduit, Pull Box, Cable, Testing	11500	LF	$ 6	$ 69,000	Allowance
	Ground Restoration, Seed & Plant	11500	LF	$ 5	$ 57,500	Allowance
	Cleaning & Hydrostatic Testing	1	LS	$ 100,000	$ 100,000	Allowance
				Subtotal	**$ 3,136,500**	
Main Pipeline						
	78" WSP Fabrication	11500	LF	$ 624	$ 7,176,000	5/16" wall thickness
	78" Install - Rural Residential	11500	LF	$ 524	$ 6,026,000	Parallels east side of river upstream from Cemetary Bridge. Maintain 15' clear space from levee.
				Subtotal	**$ 13,202,000**	
Appurtenances and Misc Conveyance Structures						
	River Diversion and Fish Screen	1	LS	$ 556,400	$ 3,104,000	USACE price allowance with escalation
	Trenchless river crossing near Cemetary Bridge	1	LS	$ 445,120	$ 2,232,000	Assumes vertical shafts approximately 45 feet deep, 78-inch WSP carrier pipe in 90-inch WSP casing.
				Subtotal	**$ 5,336,000**	
Totals						
				Subtotal	**$ 21,674,500**	
		12%	Design and Admin		$ 2,600,940	
		25%	Contingency		$ 5,418,630	
				Subtotal	**$ 29,694,070**	
			Total Facility Cost		**$ 29,694,000**	

Walla Walla County Conservation District
325 North 13th Avenue
Walla Walla, WA 99362-9526
(509) 956-3777
Wwccd.net

October 23, 2019

Chet Sater
US Bureau of Reclamation
Umatilla Field office
32871 Diagonal Blvd, Hermiston, OR 97838
csater@usbr.gov

Re: Bi-State water supply data gap for the Walla Walla Basin

Dear Mr. Sater,

Please accept this letter of support for additional work addressing water supply data gaps in the Walla Walla Basin as proposed by the Walla Walla Basin Watershed Council.

The Walla Walla County Conservation District (WWCCD) is committed to resolving environmental concerns through local solutions. The WWCCD has worked with several irrigation districts and individual irrigators over the past two decades to reduce consumptive use by installing flow meters (and fish screens) on diversions, converting earthen canals to piped systems, and other irrigation efficiency practices.

Now the challenge is to think outside the box to increase flows for fish while continuing existing agricultural and municipal water use. Our Walla Walla Basin is complex and we need a solution to resolve water supply and tribal concerns. While several alternatives have been partially vetted, additional data gaps remain. A USBR grant will address some data gaps and ensure that the efforts of over 20 stakeholders continues with the best information possible.

Thank you for your consideration.

Renee M. Hadley
District Manager

Walla Walla Watershed Management Partnership

For Fish. For Farms. For Everyone.

November 12, 2019

Chet Sater
US Bureau of Reclamation
Umatilla Field Office
32871 Diagonal Blvd.
Hermiston, OR 97838

Dear Mr. Sater:

This letter is in support of the grant request made by the Walla Walla Basin Watershed Council (WWBWC) for addressing water issues in the Walla Walla Basin.

Working with the WWBWC, we are attempting to address long-term water supply issues with many other stakeholders in the basin. We have an instream flow study, which is ongoing, and is largely paid for by the Washington Department of Ecology. This work proposed by the WWBWC would complement the work we are doing under this study.

The Walla Walla Basin is very complex, and an additional challenge we face is that two states are within the basin. We still need to obtain information on additional data gaps, and there are some actions that need to be taken in Oregon, for which Washington State dollars cannot be used. Bureau of Reclamation & Oregon Water Resources Department funding would address that need.

Sincerely,

Chris Hyland

Chris Hyland, Executive Director
Walla Walla Basin Watershed Management Partnership

cc: Scott Tarbutton, Washington Department of Ecology