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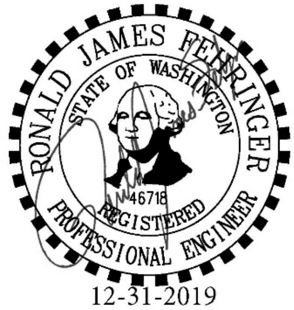

Memorandum

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Subject	**Bennington Lake Utilization**
Project Name	Feasibility, Data Analysis, and Environmental Review for the Walla Walla Basin Integrated Flow Enhancement Study
Attention	Chris Hyland, Walla Walla Watershed Management Partnership (WWWMP)
From	Ken Hansen, Jaco Esterhuizen, Perrin Robinson, and Ron Fehringer - Jacobs Engineering Group, Inc. (Jacobs)
Date	December 31, 2019
Copies to	Brian Wolcott, Walla Walla Basin Watershed Council (WWBWC)

1. Introduction

1.1 Background

Jacobs Engineering Group, Inc. was tasked to provide a follow-up investigation for use of Bennington Lake as a source of water for the Walla Walla River as part of project development under the Walla Walla Basin Integrated Flow Enhancement Study (Flow Study). The previous characterization of Bennington Lake for water supply was that existing water storage for the sole purpose of restoring fish flows is not feasible. Existing storage is allocated to flood mitigation when there is surplus water available in Mill Creek. Water supply after the historical safe fill date restricts filling Bennington Lake. The normal (50 percent exceedance) volume is only 1,600 acre-feet (AF) when maintaining the recommended ecological flows in Mill Creek (Stillwater Sciences 2013). Additional storage would have to be created by excavating the bottom of the reservoir and repairing the dam to allow for long-term storage.

1.2 Authorization

This task was authorized in November with the contract expiring at the end of December. Due to reduced interest in Bennington Lake, the scope of the task was significantly reduced. The reduced interest was primarily due to concerns that expanding Bennington Lake would conflict with the Mill Creek General Investigation (GI) being performed by the U.S. Army Corps of Engineers (USACE) Walla Walla District. However, the reduced scope made completion feasible given that the authorization of this task overlapped with completion of the 2019 Walla Walla River Bi-State Flow Study Report (Jacobs, Aspect 2019) for the overall 2018-2019 biennium contract and the holidays.

1.3 Purpose

The purposes of this technical memorandum are to:

1) Present current status of the Mill Creek GI being performed by USACE.
2) Use the limited available information to characterize the upper and lower boundaries of rough order-of-magnitude construction costs for developing long-term storage for the sole purpose of augmenting flow in the Walla Walla River to aid in restoring fish flows.

3) Determine the water availability for potential filling 4,200 AF of storage in Bennington Lake for the sole purpose of aiding restoration of fish flows in the Walla Walla River and not part of the Mill Creek flood mitigation.

2. Status of Mill Creek General Investigation

As previously stated, the timing of the authorization presented challenges in obtaining existing information from previous USACE studies. The desire was to review and use information developed by USACE pertaining to the Mill Creek GI and Bennington Lake seepage and dam abutment concerns for prolonged water storage. The following is a summary of tasks completed:

1) Emails and phone calls were made to the project manager with the Planning Division for the Mill Creek GI with no success of making contact. It was not a surprise given the short notice and timing of the holidays.
2) A morning visit to the district office was performed prior to the December Flow Study Steering Committee meeting on December 5, 2019. Ken Hansen (Jacobs) was able to meet with key personnel at USACE to inform this investigation. Tracy Schwarz in the engineering group was able to provide technical information and establish contacts for getting bathymetric information. Yvonne Palmer, though not involved with the Mill Creek GI, provided some geotechnical information. The project manager, Alex Colter, was not able to be reached.
3) USACE notified us that any written or prepared documents or information from the Mill Creek GI would not be available to inform this investigation. However, it was unofficially communicated that the preferred recommendation is to raise the existing levees and not increase the storage at Bennington Lake. Apparently, increasing flood storage would provide an infrequent benefit due to the incremental increase in flood protection as compared to protection provided more frequently by increasing the levee height. Given this reasoning, expanding storage at Bennington Lake for the sole purpose of restoring fish flows is not in conflict with the GI and provided justification to explore further.
4) In the weeks following the December 5 meeting, USACE provided:
   - Raw topographical information (LiDAR) at Bennington Lake and the surrounding area
   - Exploratory geotechnical borings near the dam

3. Bennington Lake Enlargement Design Assumptions

With limited information and a narrow task scope, simplifying design assumptions were made to develop an excavation and reservoir enlargement concept. Because of the lack of additional information, assumptions were made to be consistent with design concepts and approaches previously considered and discussed by USACE. The following is a brief summary of the assumptions and existing information adopted for the investigation:

1) **Stage-Area-Storage relationship** – The recently provided topographical information was assumed to represent the existing reservoir storage levels. A comparison is made with the storage values from the 2006 Mill Creek Water Control Manual (USACE 2006) with the conservation pool elevation being the assumed datum (storage values were equalized at the conservation pool). Table 1 provides the stage-area-storage summary with respect to some key characteristics of Bennington Lake.

Table 1. Key Bennington Lake Stage-Area-Storage Summary of Key Features

Stage (feet)	Area (acres)	Storage (AF)	Storage from Water Control Manual[a] (AF)	Feature
1180.0	N/A	NA	16	Effective reservoir bottom
1205	46	866	866	Conservation pool
1214	60.1	1,340	1,410	Dam cutoff wall top elevation

Table 1. Key Bennington Lake Stage-Area-Storage Summary of Key Features

Stage (feet)	Area (acres)	Storage (AF)	Storage from Water Control Manual[a] (AF)	Feature
1235	108.6	3,106	3,330	Maximum WSE for prolonged storage above conservation pool; 15 days maximum allowable time for storage above WSE 1235 due to seepage.
1247	144.9	4,617	4,932	Sill of diversion dam sluice gate
1252	161.9	5,384	5,739	Sill of intake canal headworks
1253	165.8	5,548	5,913	Lower limit diversion forebay of operating level
1254.5 to 1255.5	174.9 (at WSE 1255)	5,889 (at WSE 1255)	6,184 to 6,369	Diversion forebay operating level per recommendations in the Mill Creek Fish Bypass Plan for optimal discharge for fish passage through the fish ladder.
1256	N/A	N/A	6,462	Upper limit of diversion forebay operating level
1261	N/A	N/A	7,459	Crest of diversion spillway
1265	N/A	N/A	8,327	Maximum pool elevation for flood control
1269	N/A	N/A	N/A	Top of diversion dike
1270	N/A	N/A	N/A	Dam crest elevation

[a] Storage values from Mill Creek Water Control Manual for reference and comparison only

N/A = not applicable

WSE = water surface elevation

2) **Water levels** – It is assumed that the active storage would be between the conservation pool (water surface elevation [WSE] 1205) and the Maximum WSE for Prolonged Storage (WSE 1235). The maximum water level in Bennington Lake assumed to not restrict flood diversions from Mill Creek is the sill of the canal intake (WSE 1252).

3) **Storage Volume** – The targeted expanded storage volume is to provide approximately 4,000 AF. It is assumed that the total reservoir storage (existing and enlarged) can be used between WSE 1205 and 1235 if the amount of flood storage below the sill of the canal intake (WSE 1252) is not reduced.

4) **Excavation Depth** – A conglomerate layer at the top of the bedrock is assumed to limit the depth of excavation because it is believed to be the main pathway for seepage. The depth of overburden material above the conglomerate layer varied between approximately 70- and 100-feet based on the exploratory borings provided by USACE.

5) **Excavation Material** – The excavation material is primarily silt with an occasional siltstone layer with an approximate thickness of 5 to 7 feet. The material should be relatively easy to excavate if water management does not become an issue.

6) **Excavation Volume** – Using the LiDAR information provided by USACE, excavation of an area of approximately 100 acres at elevation 1205 was determined to achieve the approximate targeted expanded storage volume of 4,000 AF. An island near the intake canal was assumed to provide a good opportunity to obtain the area required. Figure 1 shows the excavation area at elevation 1205 and cut slopes. The cut slopes were assuming a slope of 5 horizontal to 1 vertical. The volume of excavated material is estimated to be 10.2 million cubic yards or 6,300 AF.

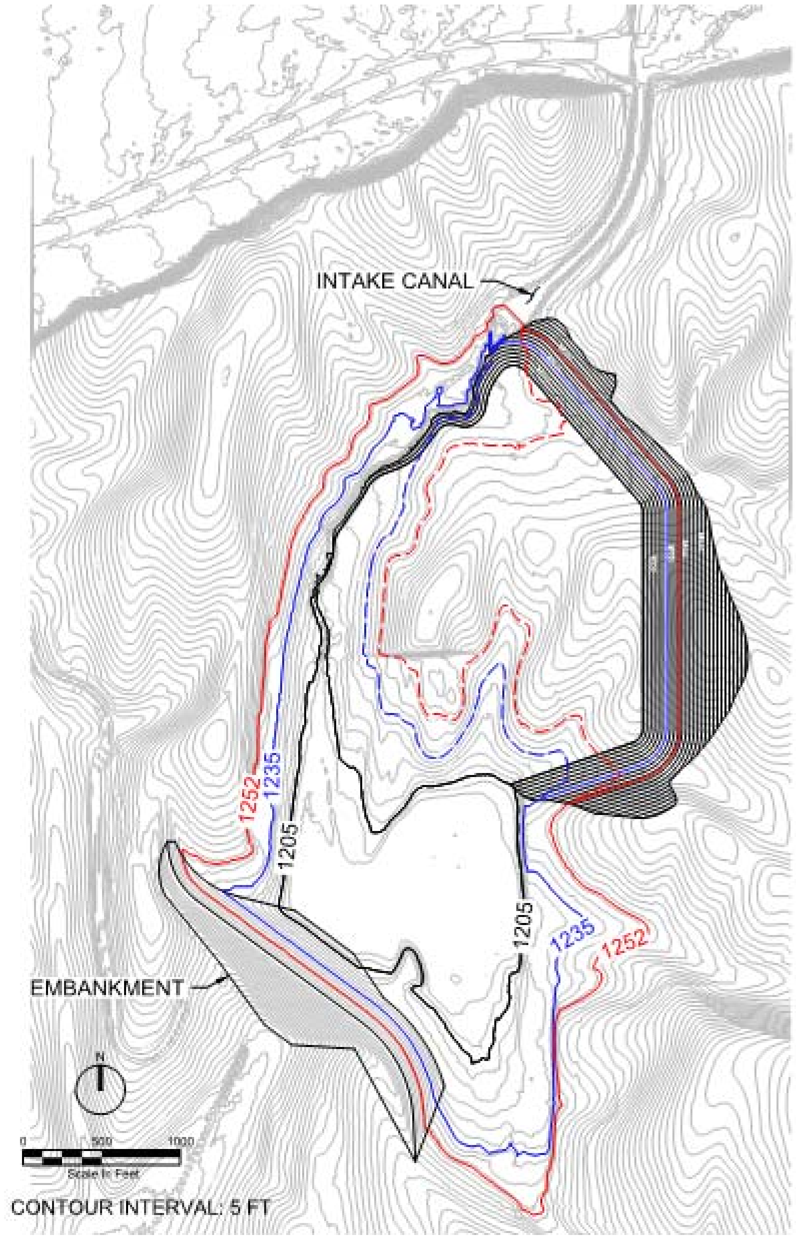

Figure 1. Topographical Map of Bennington Lake with the Excavation for the Enlargement
LiDAR information provided by USACE Walla Walla District
Source of the LiDAR is understood to be from the City of Walla Walla

7) **Material Placement** – It is assumed that adjacent lands are suitable and can be purchased within a quarter-mile distance.

8) **Seepage Mitigation** – A geosynthetic liner is assumed to be required for mitigation of the seepage in order to store water at a pool elevation of 1235 for a long time period.

9) **Infrastructure** – Bennington Lake is part of the Mill Creek Flood Control Project for the purpose of flood mitigation and providing public recreation at the conservation pool. A majority of the infrastructure (including the intake headworks, intake canal, fish screens, outlet works) are assumed to be used with some expansion and enlargement.

10) **Conveyance** – For Mill Creek flows to be a viable source of water supply for fish flow augmentation on the Walla Walla River, the water needs to be conveyed to the upper irrigation diversions in

Oregon. Bennington Lake has the potential to provide a gravity water supply with the low reservoir WSE of 1205 and the approximate WSE of 987 at the FROG. For the Pine Creek Reservoir Concept Study (CH2M HILL 2017), a pipeline alignment and profile were developed from the existing outlet works of Bennington Dam and connected to the proposed 940 pipeline. The pipeline was sized to provide a diversion capacity of up to 20 cubic feet per second, resulting in a 36-inch diameter high-density polyethylene pipe. A conceptual construction cost estimate was prepared for the pipeline with a total construction cost of $23,674,000.

Digital terrain modeling calculated a difference between the enlarged and existing storage of approximately 4,200 AF while not impeding flood diversions at the assumed maximum water level (WSE 1252). The storage value of 4,200 AF is acceptable given that it is close to the desired volume of 4,000 AF and the total storage capacity at the WSE 1235 can accommodate both the 4200 AF for long-term storage and the 866 AF of the storage for the conservation pool. . The existing and enlarged storage values at different reservoir stages are shown in Table 2 and on Figure 2.

Table 2. Comparison of the Existing and Enlarged Bennington Lake Stage-Storage with Noted Key Features

Stage (feet)	Existing Storage (AF)	Enlarged Area (acres)	Enlarged Storage (AF)	Delta Storage (AF)	Feature
1205	866	143.4	866	-	Conservation Pool
1210	1,114	150.9	1,602	488	
1214	1,340	157.2	2,218	878	Dam cutoff wall top elevation
1215	1,401	158.8	2,376	975	
1220	1,738	167.9	3,193	1,455	
1225	2,132	178.2	4,057	1,925	
1230	2,591	187.6	4,972	2,381	
1235	3,106	196.8	5,932	2,826	Maximum WSE for prolonged storage above conservation pool (15 days)
1240	3,683	208.7	6,945	3,262	
1245	4,334	220.4	8,018	3,684	
1250	5,067	231.2	9,147	4,080	
1252	5,384	235.2	9,613	4,229	Sill of intake canal headworks[a]
1255	5,889	243.7	10,331	4,442	

[a] Maximum water level in Bennington Lake assumed to not restrict flood diversions from Mill Creek

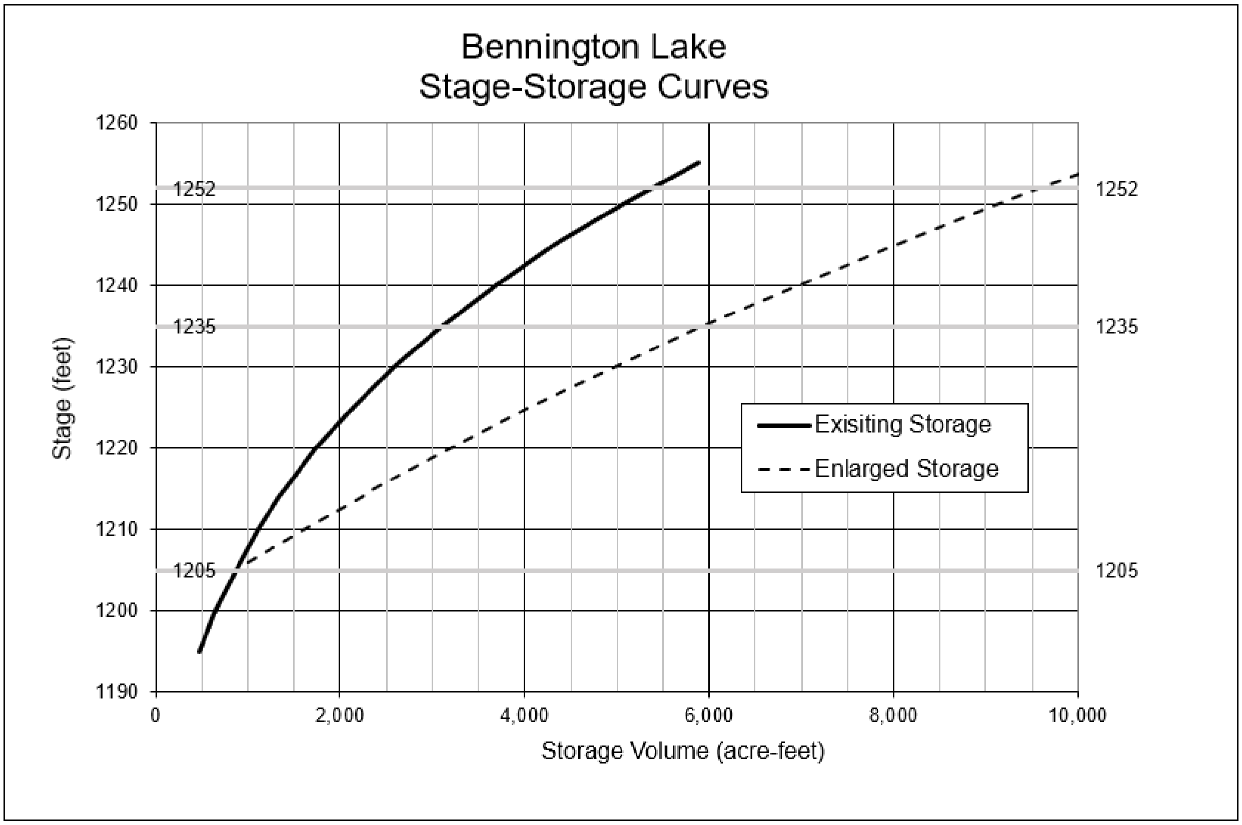

Figure 2. Stage versus Storage for Existing and an Enlarged Bennington Lake
LiDAR information provided by USACE Walla Walla District
Source of the LiDAR is understood to be from the City of Walla Walla

4. Enlarged Bennington Lake Fill Potential

4.1 Mill Creek Water Supply

An analysis of Mill Creek flows to fill the potential enlarged Bennington Lake storage volume was performed using the same information as in the previous analysis from two stream gages: Mill Creek at Kooskooskie and Mill Creek at Walla Walla. The Mill Creek at Kooskooskie gage is located upstream of significant diversions with a drainage area of 59.6 square miles. The Mill Creek at Walla Walla gage is located below the diversion dam and below the Yellowhawk/Garrison diversion works with a drainage area of 95.7 square miles. The Kooskooskie gage does not include a significant tributary, Blue Creek. The Mill Creek at Walla Walla gage had several data gaps. The maximum value of the two gages was used to determine the water available for diversions to Bennington Lake.

4.2 Mill Creek Ecological Flows

As before, the recommendation for ecological flows in Mill Creek were derived from the Stillwater report (Stillwater Sciences 2013) commissioned by CTUIR and served as the basis for the winter and spring flow recommendations (See Table 3)

Table 3. Recommended Instream Flow Subscriptions for Ecological Flows in Mill Creek

Time Period	Mill Creek Reach 2 (Below Bennington)
OCT	46 cfs
NOV	55 cfs
DEC	64 cfs
JAN	74 cfs
FEB	88 cfs
MAR	104 cfs
APR	149 cfs
MAY	110 cfs
JUN	72 cfs
JUL	52 cfs
AUG	45 cfs
SEP	45 cfs

Flow Recommendation from Stillwater (Stillwater Sciences 2013)

4.3 Fill Potential Simulations

Simulations using historical data were performed to further characterize the potential for filling the reservoir. The scenario for estimating the fill volume potential for Bennington Lake was performed making the following assumptions for key parameters:

a) The scenarios are primarily differentiated by assuming minimum instream ecological flows for Mill Creek using the flow subscriptions for ecological flows (Stillwater Sciences 2013).

b) Available flows were determined using the maximum flow from either Mill Creek gage at Walla Walla or Mill Creek at Kooskooskie gage to capture winter flows and avoid large data gaps. The water supply estimate should be conservatively low.

c) The fish screen flow capacity at the river diversion was assumed to be increased from the existing capacity of 30 cfs to 120 cfs.

d) The period of the simulation was from Feb 1 thru May 31.

e) The fill potential storage volume was not limited by the reservoir storage as there is potential that the storage could be expanded.

The conclusion was that Mill Creek water supply, as limited by the ecological flows, could fill the potential 4,200 AF added Bennington Lake storage volume approximately 80% of the time as shown in Figure 3. Figure 3 also shows the estimated fill volume for the existing reservoir that is restricted by the safe fill date so as not to conflict with flood mitigation.

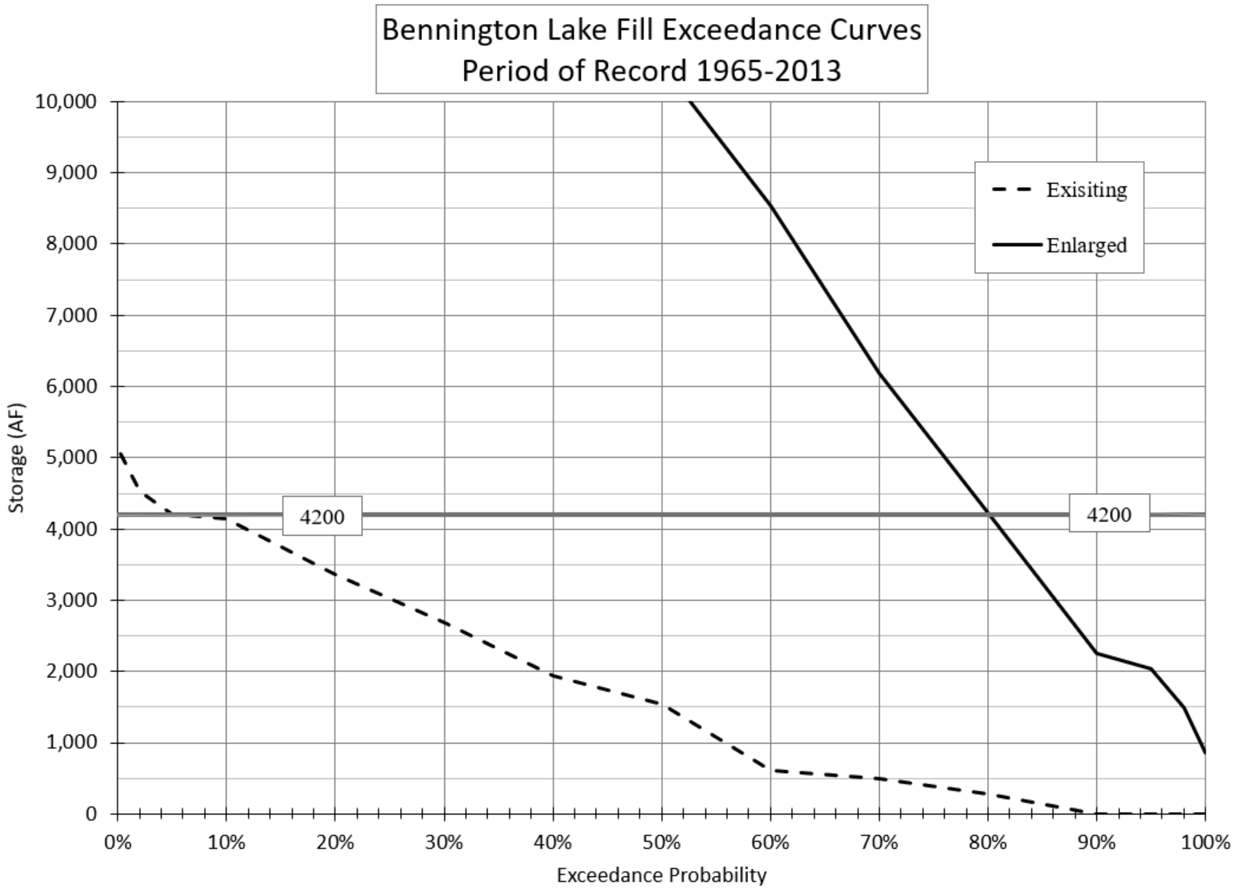

Figure 3. Potential Fill Volumes for Bennington Lake

Flow Record provided by USACE

The flow subscriptions for ecological flows are from the Stillwater Sciences report (Stillwater Sciences 2013)

5. Capital Cost Characterization

5.1 General

The design and cost opinions are conceptual given the late authorization for the task, limited information available, limited scope, and lack of availability of cost estimators during the holidays.

5.2 Approach

The potential capital construction costs were characterized by enveloping the cost between lower limit and an upper limit cost estimates for enlarging Bennington Lake storage. The envelope approach bound the costs by developing both a high and low estimate recognizing what features dictate or drive the majority of the cost. The excavation and geosynthetic liner are the cost drivers for the enlargement of Bennington Lake.

5.3 Excavation Volume

Both the method of excavation and the excavation volume have bearing on the construction cost. The theoretical minimum excavation is the desired water volume of 4,200 AF. Unfortunately, it is difficult to achieve this volume with relatively flat cut slopes and the island extending significantly above the assumed high WSE of the active storage (1252). As previously stated, the excavation volume is 6,300 AF or 150 percent of the desired water volume. Excavation has not been optimized to reduce the ratio of excavation volume to water volume. For the low cost estimate, it is assumed the ratio could be optimized to 120 percent for an excavation volume of 5,040 AF. Scapers were assumed for the low cost estimate, whereas it was assumed that excavation for the high cost estimate would be accomplished by using scrapers for half of the excavation and large excavators and trucks for the other half of the excavation.

5.4 Liner

Assumptions for both the quantity and type of liner were made for the high and low cost estimates. For the high estimate scenario, it is assumed the entire bottom of the reservoir up to elevation 1240 is lined with a geomembrane. For the low estimate, a 2-foot thick earth liner is assumed at and below elevation 1205. For the slopes above elevation 1205, 50 percent of the area is assumed to be a geomembrane liner.

5.5 Cost Envelope Summary

The following is a summary of the cost characterization. It is anticipated that the cost would fall somewhere between the two limits. The recent unit costs of storage at the Pine Creek Reservoir was $15,160 per AF.

Table 4. Conceptual Capital Cost Summary for an Enlarged Bennington Lake

		Low Cost Opinion		High Cost Opinion	
Feature	**Unit**	**Quantity**	**Cost**	**Quantity**	**Cost**
Scraper Excavation	CY	10,202,200	$30,607,000	5,101,100	$15,303,000
Excavator/Truck Excavation	CY	0	-	5,101,100	$51,011,000
Geomembrane Liner	SF	1,421,100	$4,263,000	9,089,600	$27,269,000
Earth Liner	SF	6,247,300	$3,686,000	0	-
Other Appurtenances	LS	1	$1,300,000	1	$1,300,000
Subtotal			**$39,856,000**		**$94,883,000**
Markups			$15,066,000		$35,866,000
Enlarged Bennington Lake Subtotal Cost			**$54,922,000**		**$130,749,000**
Subtotal Unit Cost per AF			**$13,080**		**$31,130**
Bennington Pipeline Project			$23,674,000		$23,674,000
Total Combined Project Cost			**$78,596,000**		**$154,423,000**
Total Unit Cost per AF			**$18,713**		**$36,767**

CY = cubic yard
SF = square feet
LS = lump sum
AF = acre feet

6. Conclusion

Based on preliminary indications from USACE regarding the Mill Creek GI, the opportunity is available for added water storage in Bennington Lake. This addition storage enlargement can be used for augmenting flows in the Walla Walla River to help restore fish flows thereby complimenting either of the currently proposed Flow Study anchor projects. The cost characterization shows that enlarging Bennington Lake and constructing the Bennington Pipeline results in a unit cost on the order of $18,713 to $36,767 per AF of water supply which is greater than the Pine Creek Reservoir anchor project unit cost of $15,160 per AF of water supply.

Field data collection and engineering analysis and design effort is required to fully evaluate the potential Bennington Lake enlargement project. However, this initial investigation demonstrates that it has potential (though very expensive) as a complimentary project has validity to support the goals of the Flow Study.

7. References

CH2M HILL Engineers, Inc. (CH2M). 2017. Pine Creek Reservoir Concept Study. September.

Jacobs Engineering Group, Inc (Jacobs), Aspect Consulting, LLC. (Aspect). 2019. Walla Walla River Bi-State Flow Study. December.

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