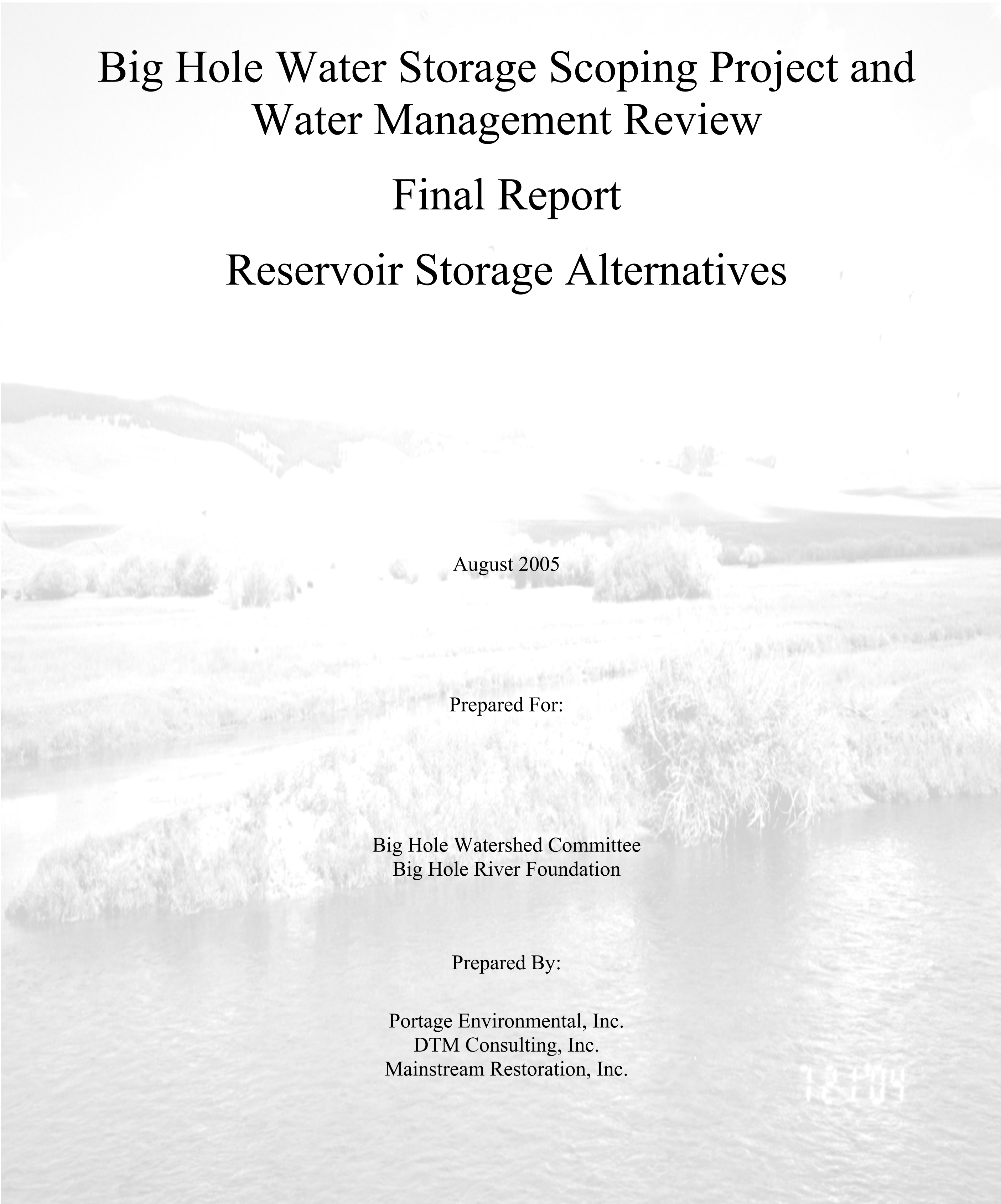

Big Hole Water Storage Scoping Project and Water Management Review

Final Report

Reservoir Storage Alternatives

August 2005

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Big Hole Watershed Committee
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ACRONYMS

ARM	Administrative Rules of Montana
BHWC	Big Hole Watershed Committee
BHRF	Big Hole River Foundation
CE	Categorical Exclusion
DOI	Department of Interior
DNRC	Department of Natural Resources and Conservation
EA	Environmental Assessment
GIS	Geographic Information System
MCA	Montana Code Annotated
MDT	Montana Department of Transportation
MFWP	Montana Fish Wildlife and Parks
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
TAC	Technical Advisory Committee
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

1. INTRODUCTION TO RESERVOIR STORAGE ALTERNATIVES

The Big Hole Watershed Committee (BHWC) and the Big Hole River Foundation (BHRF) commissioned a study in the spring of 2004 to evaluate methods of improving in-stream flows in the upper reach of the Big Hole River. Water storage alternatives and water management alternatives specific to the watershed are currently being evaluated by a project team consisting of Portage Environmental Inc., DTM Consulting Inc., and Mainstream Restoration Inc. The project is organized to evaluate water storage and all other water management alternatives in two parallel tasks. The purpose of the water storage task is to identify and analyze sites in the upper Big Hole River Basin that are suitable for reservoir storage of water which may be used to supply the Big Hole River critical grayling reach during periods of low flow.

The critical grayling reach, as identified in the Scope of Work (BHWC/BHRF, December 5, 2003) extends from Rock Creek Road to the mouth of the North Fork Big Hole River. Under the Scope of Work, the Portage team is tasked to evaluate storage for an estimated 1,200 acre-feet of water. These two criteria provide the basic water storage evaluation guidelines by establishing the point of use and needed storage quantity.

2. DAM SITING PROCESS

Working from general considerations and then narrowing the search to specifics is often the most successful approach when evaluating sites for public works or other facilities. The Portage team began this process by identifying a large number of sites that could potentially meet the project objectives. Preliminary screening guidelines based upon the feasibility of water conveyance and water delivery to point of use were then developed in order to reduce the alternatives to a manageable geographic range bounded by the following.

> North of Holland Creek: Holland Creek and tributaries to the north (Swamp Creek, etc.) drain into the main stem of the Big Hole River at a point close to the downstream end of the critical grayling reach. The release of water through these tributary watersheds would have limited value toward enhancing grayling reproduction and survival.
>
> South of Miner Creek: Watersheds south of Miner Creek (Engeljard Creek, etc.) are found at such a distance (over 10 miles) from the upper end of the critical grayling reach that the practicality of conveyance without significant losses is greatly reduced.
>
> East of Big Hole River: With the exception of an off-channel impoundment for water drawn and returned to/from the Big Hole River, areas east of the Big Hole River are less desirable water storage sites due to relatively low watershed yields found at the east side of the valley.

Within these geographic bounds field reconnaissance was performed at nine locations, the potential reservoirs were plotted to site topography to show scale, and a preliminary matrix was developed to assist the BHWC in evaluating the technical feasibility of each of the nine sites. The Alternative Summary Matrix is shown in *Appendix A, Reservoir Storage Alternatives Summary Matrix*.

The criteria used to evaluate each of the nine sites are shown in *Table 2-1 Reservoir Storage Alternative Evaluation Criteria*. With input from the BHWC, the list of potential sites was reduced to 5 for cost analysis and more detailed evaluation. This phase of the evaluation consisted of development of a conceptual design and analysis of capital and operation and maintenance costs. The results of the preliminary screening of nine initial sites and the results of cost analysis for the five sites selected for further evaluation is detailed in this report. Also included in the report are recommendations and projected costs for environmental and geotechnical work at selected reservoir sites.

Table 2-1. Reservoir Storage Alternative Evaluation Criteria

CRITERIA	CONSIDERATIONS FOR PRELIMINARY SCREENING
General site suitability	• Land ownership • Site access • Zoning requirements • Current land use • Potential land use
Geology and Hydrogeology	• Soils and bedrock • Faults and seismic impacts • Stability • Groundwater • Flood hazard
Engineering feasibility	• Size and capacity for intended use • Topography • Water storage/leak projections • Construction materials availability • Site assessment requirements
Environmental	• Water quality • Wetlands • Vegetation and wildlife • T&E species
Social and economic	• Traditional cultural values • Visual impacts • Recreational opportunities • Traffic and public use • Local economic impacts
Administrative	• Management • Operations and maintenance • Legal issues

3. SEDIMENTATION DISCUSSION

The U.S. Geological Survey (USGS) reports that sediment decreases the storage capacity of large reservoirs in the United States by 0.22% annually. The figure is slightly less at 0.18% annually for the Mountain region. In other words, a large reservoir in the Mountain region having a design life of 100 years could lose 18% capacity over that period. This data is derived from studies involving reservoirs with total capacities of 5,000 acre-ft. Another statistic, the typical vertical accretion rate in reservoirs (within the National Inventory of Dams) across the United States, is 4 cm/yr (S.V. Smith et al, 2002). Having a standard deviation of 4 cm/yr, this value can vary widely.

The rocks found in the Beaverhead Mountains southwest of Wisdom are mapped as Precambrian "Belt Series," and typically have low average annual sediment yields (perhaps 10 to 100 tons annually per square mile) in undisturbed basins. Land use disturbances (e.g., roads, timber harvests) and natural occurrences (wildfires, landslides, debris flows, etc.) would create potential sources of sediment that are difficult to predict.

The importance of sedimentation to water storage in the Upper Big Hole River basin is that, over time, reservoir capacity will be reduced and the annual release of usable water will diminish. For purposes of sizing reservoirs in this study, it is assumed that a 20% loss in capacity will occur over the design life of each reservoir due to sedimentation. Based on the geologic setting and current land status of the tributary watersheds, this figure is believed to be conservatively high

4. EVAPORATION DISCUSSION

The creation of a reservoir increases water surface area relative to that found in flowing streams and rivers. The increased surface area results in greater evaporative losses. This is somewhat offset by direct precipitation upon the water body. The net water balance (precipitation minus evaporation) must be accounted for when comparing water management alternatives (reservoir vs. no reservoir) and when appropriating water.

Annual average precipitation at both Jackson and Wisdom is approximately 12 inches. Total precipitation increases with elevation. Free water surface evaporation rates in the larger valleys of southwestern Montana are near 30 inches/year. Interpolation of contours found in the *Evaporation Atlas for the Contiguous 48 United States* (National Oceanic and Atmospheric Administration, 1982) indicates that the free water surface evaporation rate the Upper Big Hole River Valley is less than 30 inches/year.

The timing by which water is collected and released in a reservoir affects the pool surface area and associated evaporation rate. In consideration of these factors, annual net evaporative losses to the reservoir storage alternatives are expected to be near 5 % of the total storage volume. It should be noted that although water is lost by evaporation, this loss is minor compared to the overall water balance of the reservoir which is primarily controlled by the reservoir's inflow, seepage, and outflow. However, evaporation losses compete with other water uses and are therefore an issue in considering the net benefit of a reservoir.

5. SUB-BASIN YIELD DISCUSSION

In examining the feasibility of locating a small reservoir in a given drainage, sub-basin yield was estimated as a screening step. The estimate uses the Big Hole Basin Geographical Information System (GIS) database to calculate the average precipitation in a sub-basin adjusted for elevation. GIS is also used to estimate the drainage area. *Table 5-1. Upper Big Hole Basin Estimated Watershed Yield* shows the estimated yield for each sub-basin.

The nearest stream gage relative to storage sites is located on the Big Hole River near Jackson, Montana. The gage is located one mile downstream from Pioneer Creek and nine miles southwest of Jackson. The period of record is from May 1940 to October 1954, and the records are not continuous for the winter months (DNRC, 1979). Although the records are limited, an estimate of annual stream flow for a known basin size in the region can be derived from this information.

To infer other watershed yields based on available stream gage data, two basin characteristics are used. The first is average annual precipitation (a function of basin elevation) and the second is basin area. Scaling factors are derived by proportioning each of these characteristics to the known basin characteristics (associated with the Jackson gage). Estimated watershed yield is the product of these scaling factors and the recorded annual stream flow.

Although this method is approximate, watershed yield estimates are reasonable for purposes of comparing storage alternatives. The estimates are derived by correlating similar-sized basins having many like characteristics, such as climate, elevation, relief, aspect, geologic structure, and vegetation.

Table 5-1. Upper Big Hole Basin Estimated Watershed Yields

Estimates Based on Jackson Gaging Station, Scaled to Basin Areas and Precipitation			
Jackson Gaging Station Data:			
Average Annual Precipitation	34.97	inches	
Watershed Area	47.99	sq. mi.	
Average Annual Total Flow*	37,753	acre-ft	
Alternative	Average Annual Precipitation (in.)	Watershed Area (sq. mi.)	Estimated Annual Yield (acre-ft)
Dry Creek	28.94	52.09	33,914
Lower Big Lake Creek	35.48	17.34	13,839
Big Swamp Creek	35.92	16.58	13,396
Lower Miner Lake	36.74	17.13	14,158
Big Swamp Creek, Upper Site Only	36.81	10.67	8,835
*As reported by DNRC, Potential Off-Stream Reservoir Sites in the Big Hole River, 1979.			

6. RESERVOIR HEATING DISCUSSION

An important component of examining the feasibility of reservoir storage for sustaining artic grayling during periods of low in-stream flow is temperature. Shallow bodies of water can be subject to excessive heating and many deep water bodies will react as a heat or cold sink with ambient temperatures; giving up its heat or cooling at a rate and within a narrower range of temperatures than the ambient atmosphere. Heat exchange and thermal stratification in a reservoir of the scale considered in this study is affected by many variables, including the temperature of the inflow waters, climate and elevation, shading, depth, wave height, and other factors that effect vertical mixing.

Existing models for predicting temperature fluctuations are available, but are complex and would require significant cost to develop for a specific site. These models include CE-QUAL-W2, a two dimensional basin scale water quality model used to assess impacts on rivers, reservoirs, lakes and estuaries. CE-QUAL-W2 was developed by the U.S. Army Corps of Engineers (USACE) and has been used to model sections of the Lower Snake River in Idaho and Oregon and the Bull Run River basin in Oregon (Portland State University, 2004). The USACE WQRSS and HEC-5Q, and EPA's DYNHYD are other basin scale water quality models used by water managers. Proprietary models are also available for predicting temperature fluctuations, stratification and other water quality parameters such as dissolved oxygen and predictions of utrophication.

For the purpose of approximating the temperature variations that may be expected in a reservoir located in the Upper Big Hole Basin, the Portage team searched for a surrogate reservoir subject to similar climatic conditions. The U.S. Bureau of Reclamation (USBR) maintains climate and water quality data for several reservoirs across the state of Montana. Hebgen Reservoir located approximately 10 miles north of West Yellowstone was selected for its similar elevation and climate. The major differences between Hebgen and the conceptual designs presented in this report are the reservoir size (Hebgen is a much larger reservoir with a maximum capacity of approximately 375,000 acre-feet), Hebgen is a deeper water body, and Hebgen is fed by the Upper Madison River (a larger inflow than any of the conceptual designs considered in this report). Data on thermal stratification was not readily available, but due to its depth Hebgen Reservoir is not expected to be completely mixed. Outflow temperatures are readily available.

Factors that mitigate reservoir heating at the sites considered in this report are shading or the percentage of time during the day when the reservoir is not exposed to direct solar radiation due to vegetative cover, aspect and surrounding topography; cloudiness; and the lack of thermal waters (which are present on the Upper Madison). The conceptual designs shown in this report all draw water from the bottom of the reservoir dam which ensures that cooler water is discharged if the reservoir is thermally stratified during summer months. On-channel storage and associated inflow would moderate both water temperature and thermal stratification at the sites considered. The small seepage sites design concept assumes continuous cold spring water inflow and discharge which would also help moderate temperatures. The following tables show a comparison of climate data between Hebgen Dam and Wisdom Montana and the ambient air temperature and outflow water temperature relationships at Hebgen Dam.

Table 6-1. Summary Statistics for Wisdom and Hebgen Dam

	Jan		Feb		Mar		Apr		May	
	Wisdom	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**
Average Max (°F)	26.6	21.9	31.1	27.8	38	36.4	48.6	46.6	59.4	59
Average Min (°F)	1.8	2.9	3.7	5.1	10.4	11.6	20.8	22.4	28.6	31.4
Average Total Precipitation (in.)	0.69	3.09	0.52	2.43	0.69	2.4	0.92	1.92	1.66	2.89
Average Total Snowfall (in.)	12.8	47.3	8.4	36.5	8.1	29.8	3.8	10.5	2.4	2.8
Base 65°F Heating Degree Days	1575	1631	1346	1367	1264	1274	909	917	650	611
	Jun		Jul		Aug		Sep			
	Wisdom	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**		
Average Max (°F)	68.2	68.7	78.3	78.2	77.2	77.1	66.8	66.8		
Average Min (°F)	35.8	38.2	37.5	43.5	34.5	42.5	27.3	35.5		
Average Total Precipitation (in.)	1.9	3.03	1.1	1.76	1.09	1.75	0.98	1.72		
Average Total Snowfall (in.)	0.6	0.3	0	0	0	0	0.3	0.4		
Base 65°F Heating Degree Days	391	347	224	140	286	167	537	417		
	Oct		Nov		Dec		Annual			
	Wisdom	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**	**Wisdom**	**Hebgen Dam**		
Average Max (°F)	54.5	52.1	37.3	33.4	27.7	22.8	51.1	49.2		
Average Min (°F)	20.4	27.6	12.2	17.1	3.5	5.3	19.7	23.6		
Average Total Precipitation (in.)	0.77	1.71	0.77	2.49	0.76	3.11	11.85	28.31		
Average Total Snowfall (in.)	1.6	5.2	7.8	27.2	11.3	48.1	57.2	208.1		
Base 65°F Heating Degree Days	853	781	1207	1192	1531	1578	10775	10430		

Table 6-1, Summary of Statistics for Wisdom and Hebgen Dam shows that Wisdom and Hebgen Dam have similar climates with the exception of snowfall and precipitation. It is expected that the higher elevation reservoir sites conceptualized in this report would experience greater precipitation than that observed in Wisdom. The Wisdom station is at 6,060 feet above mean sea level while the Hebgen Dam Station is located at 6,490 feet above mean sea level. The average annual high and low temperatures between the two stations differ by 0.9 and 3.9 degrees F respectively. Average base 65 degree F heating days are comparable at 10,775 days in Wisdom and 10,430 days at Hebgen Dam over the 56 year period of record. The data indicates that Wisdom experiences greater temperature extremes – all time record lows of -55 degrees F vs. -45 degrees F at Hebgen Dam and all time record highs of 98 degrees F vs. 96 degrees F at Hebgen Dam.

Table 6-2. Year 2004 Summary Statistics at Hebgen Dam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average Storage (acre-feet)	285928	276379	267730	269266	301296	363896	381549	371009	356757	304570	297709	292800
Mean Air Temperature (°F)	11.67	16.53	30.44	37.69	43.34	52.19	59.71	56.46	48.18	41.5	20.79	18.91
Max Air Temperature (°F)	34.1	41	60.4	67.4	72	78.3	87.6	86	80.4	72.1	45.9	36.7
Min Air Temperature (°F)	-23.4	-18.8	-3.8	0	0	33.7	38	35.5	28.1	4.3	-4.9	-4.8
Mean Water Temperature (°F)	36.96	36.72	36.83	38.44	48.06	53.06	57.94	60.75	58.53	52.8	40.64	36.87
Max Water Temperature (°F)	37.7	37.5	38.3	41.7	51.8	60.4	62.2	63.9	61.9	56.2	47.2	37.4
Min Water Temperature (°F)	36.4	36	35.5	36.9	40.1	48.9	51.9	56.7	54.6	46.8	35.2	36.4

Table 6-2, Year 2004 Summary Statistics at Hebgen Dam shows the summary statistics for air and water temperatures at Hebgen Dam. Table 6-2 and *Figure 6-2, 2004 Daily* show that during the warmest period of the year, air temperatures may rise almost 40 degrees F in a 24 hour period while water temperature variability is under 3 degrees F. *Figure 6-1, Air Vs Water Temp Hebgen Dam* shows the seasonal lag of average water temperatures behind average atmospheric temperatures.

Figure 6-1. Air Vs Water Temp Hebgen Dam

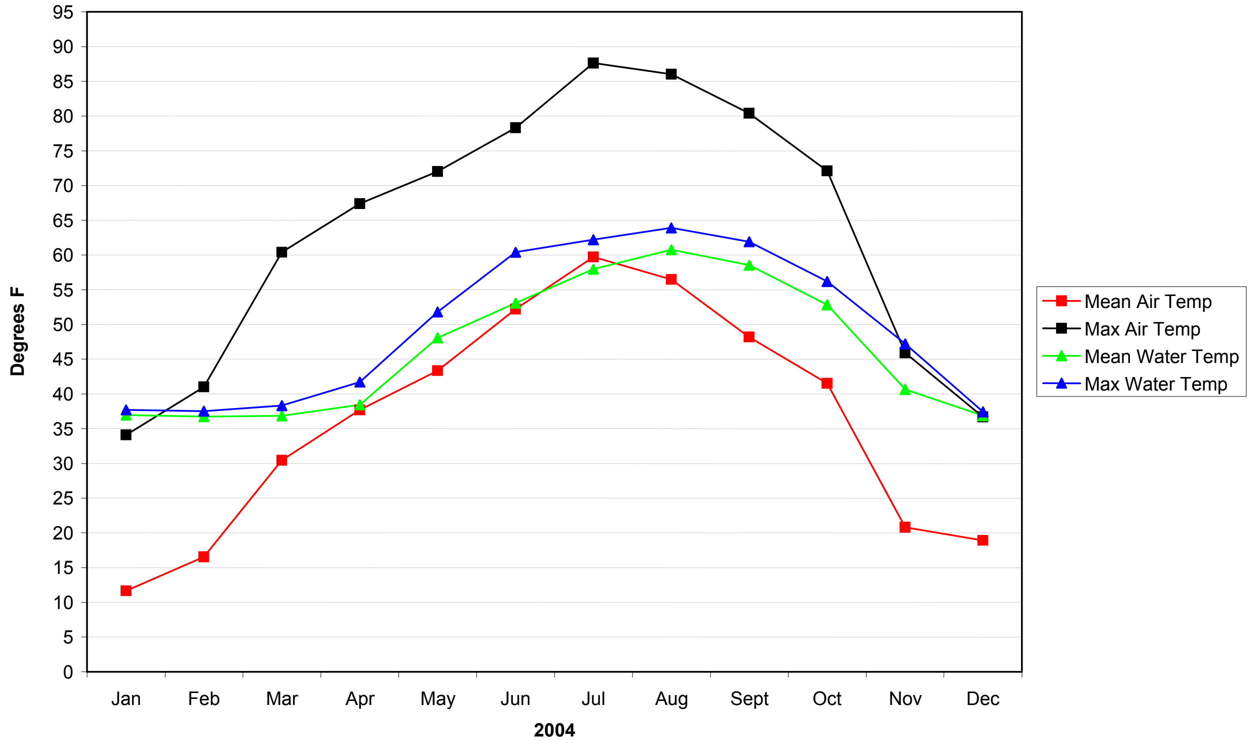
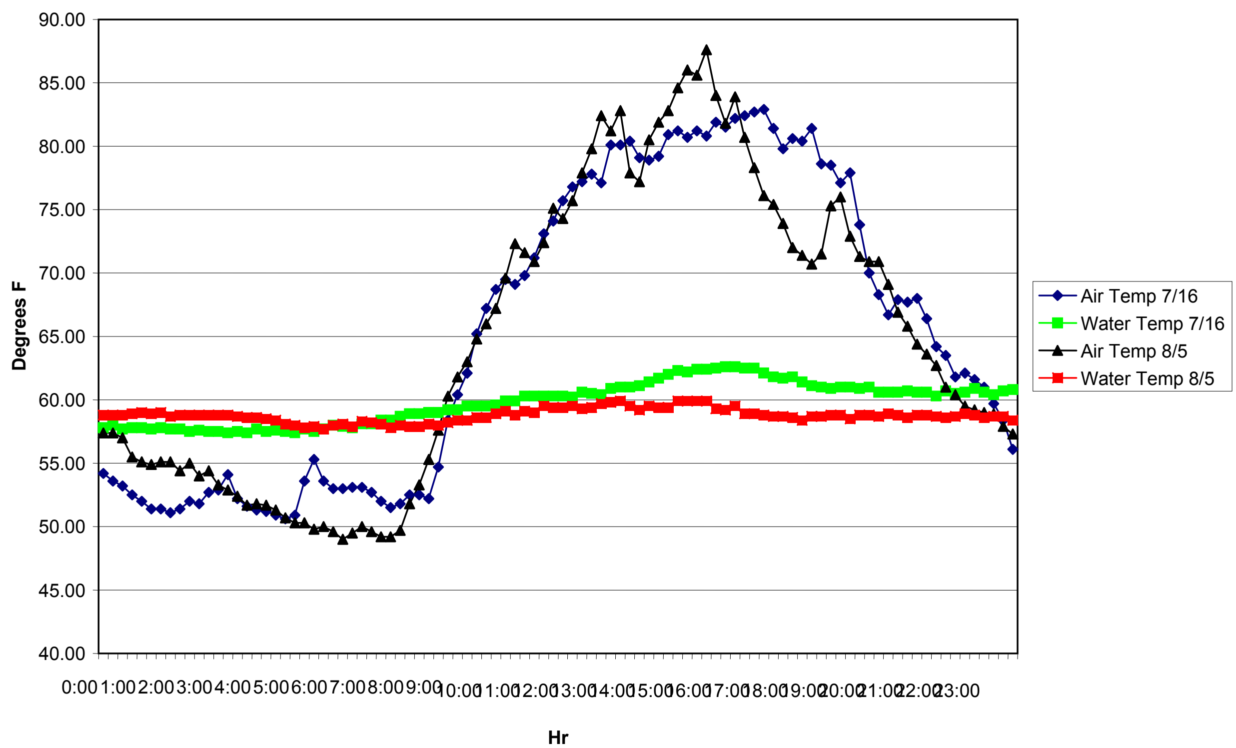


Figure 6-2. 2004 Daily



7. PRELIMINARY SITE SCREENING

On September 16th, 2004, the Portage team met with members of the Big Hole Watershed Committee Technical Advisory Committee (TAC) to discuss the Alternative Summary Matrix and findings. The TAC consists of members of the ranching community, representatives from state and federal agencies, representatives from conservation groups, members of the guiding community, and other interested parties. The reservoir storage sites shown on *Table 7-1 Alternatives for Preliminary Site Screening* were presented to the TAC in addition to the evaluation criteria examined for each location. A descriptive summary of each alternative follows.

Table 7-1. Alternatives for Preliminary Site Screening

Watershed	Site	Description
Holland Creek and Moose Creek	Near Schultz Reservoirs	Alternative 1: Raise elevation of Upper Schultz Reservoir and construct an off-channel impoundment below Lower Schultz Reservoir.
Rock Creek and Big Lake Creek	Private land below Dry Creek	Alternative 2: Construct off-channel impoundment below Dry Creek as a holding reservoir. Divert Rock Creek and Big Lake Creek to fill the reservoir and discharge back into Big Lake Creek.
Big Lake Creek	Twin Lakes	Alternative 3: Construct a dam and increase the size of Twin Lakes.
Big Lake Creek	Hirschy Diversion	Alternative 4: Construct an on-stream dam within the narrow canyon at the Hirschy Diversion on Big Lake Creek.
Big Swamp Creek	Upper Big Swamp Creek	Alternative 5: Construct an on-stream dam along an upper reach of Big Swamp Creek.
Big Swamp Creek	Big Swamp Creek	Alternative 6: Construct an on-stream dam just below the confluence of Slag-a-Melt Creek and Big Swamp Creek.
Little Lake Creek and Miner Creek	Private land below Gravelle Creek	Alternative 7: Construct off-channel impoundment below Gravelle Creek as a holding reservoir. Divert Little Lake Creek and Miner Creek to fill the reservoir and discharge back into Little Lake Creek.
Miner Creek	Lower Miner Lakes	Alternative 8: Expand the upper part of Lower Miner Lakes by constructing a dam across the narrows between the two lake sections.
Big Hole River	State land and private land east of the river	Alternative 9: Construct a holding reservoir east of Highway 278. Convey water by pipe between the reservoir and the Big Hole River via a mechanical pump station.

Figure 7-1, Preliminary Site Location Map, shows the location of the sites identified for preliminary site screening.

Figure 7-1

7.1 Alternative 1: Schultz Reservoir System

General Description: This alternative partially utilizes existing infrastructure (dams, reservoirs, and ditches) associated with the Upper and Lower Schultz Reservoirs. A new off-stream impoundment constructed below the Lower Schultz Reservoir stores water that is collected during peak flows.

Surface Area: Upper Schultz Reservoir with improvements: approximately 24 acres.

New Impoundment: approximately 40 acres.

Capacity: Upper Schultz Reservoir with improvements: approximately 720 acre-ft

New Impoundment: approximately 1000 acre-ft.

Inflow and Outflow: Flow into the Upper Schultz Reservoir remains in the current configuration. Flow into the new impoundment is via a new ditch beginning at Lower Schultz Reservoir, which is fed by existing diversions. Flow out of the Upper Schultz Reservoir remains in the current configuration. A new lined ditch delivers water from the new impoundment to the Spokane Ditch.

Water Management and Conveyance to Point Of Use: Water delivered to the Spokane Ditch replaces water otherwise diverted upstream. This increases the flow in Rock Creek. Water monitoring and management is necessary to assure delivery of this water to the Big Hole River critical reach.

Advantages: Sedimentation within the holding reservoir is easily managed. This system delivers water into the critical grayling reach on the Big Hole River; it is the furthest downstream (on the Big Hole River) of all the water storage alternatives and closest to the critical reach.

Disadvantages: A significant amount of earthwork is needed to implement this alternative. Water temperature in the holding reservoir is a concern during late summer. At least three diversions exist between the Upper and Lower Schultz Reservoirs. The watershed has a limited capacity for supporting both irrigation and storage needs so this system may be unable to provide 1,200 acre-ft of water on a consistent annual basis. Managing this system is complex. Assuring water reaches the point of intended use requires significant monitoring and maintenance.

7.2 Alternative 2: Dry Creek Site

General Description: This alternative involves a new off-channel impoundment below Dry Creek to serve as a holding reservoir. Rock Creek and Big Lake Creek fill the reservoir which discharges back into Big Lake Creek.

Surface Area: Approximately 40 acres.

Capacity: Approximately 1600 acre-ft.

Inflow and Outflow: Flow into the reservoir is via diversions and buried pipes from Rock Creek and Big Lake Creek. Flow out of the reservoir is conveyed to Big Lake Creek by a buried pipe.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Big Lake Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical reach.

Advantages: The system is off-channel, which reduces environmental impacts and sediment concerns. Two of the larger Upper Big Hole tributary watersheds provide water, which increases the likelihood for attaining 1,200 acre-ft of water on a consistent annual basis.

Disadvantages: This site may impact the Nez Perce historic trail. Reservoir construction involves significant earthwork. Water temperature in the holding reservoir is a concern during late summer. Several diversions exist on the lower reaches of Big Lake Creek. Assuring that water will reach the point of use requires significant monitoring and maintenance.

7.3 Alternative 3: Twin Lakes

General Description: This alternative involves raising the level and increasing storage within Twin Lakes by constructing a dam. The upper Big Lake Creek watershed fills the reservoir and Twin Lakes discharge back into Big Lake Creek.

Surface Area: Approximately 280 acres.

Capacity: Approximately 8400 acre-ft.

Inflow and Outflow: Flow into the reservoir is via the natural watershed above Twin Lakes. Flow out of the reservoir is directly into Big Lake Creek.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Big Lake Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical reach.

Advantages: No ditch construction is necessary. The site has ample capacity for current and future needs.

Disadvantages: There may be serious environmental impacts to aquatic species that are unique to Twin Lakes. The existing campground area and cabin are inundated, so those facilities must be relocated or abandoned. The natural character of Twin Lakes is altered by this alternative. Extensive studies, including an Environmental Impact Statement (EIS) would be necessary to develop this alternative. Studies are necessary to determine if the site is geologically suitable or if seepage losses are unacceptable. Several diversions exist on the lower reaches of Big Lake Creek. Assuring that water will reach the point of use requires significant monitoring and maintenance.

7.4 Alternative 4: Big Lake Creek

General Description: This alternative involves creating a reservoir on Big Lake Creek by constructing a dam at the Hirschy Diversion. Water backs up behind the dam and forms a reservoir within the natural floodplain. The Big Lake Creek watershed above the diversion fills the reservoir and the reservoir discharges back into Big Lake Creek.

Surface Area: Approximately 150 acres.

Capacity: Approximately 2,500 acre-ft.

Inflow and Outflow: Flow into the reservoir is via the natural watershed above this site. Flow out of the reservoir is directly into Big Lake Creek.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Big Lake Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical grayling reach.

Advantages: No ditch construction is necessary. The site topography is favorable for constructing a dam using relatively low material quantities.

Disadvantages: There are serious environmental impacts to existing wetlands and riparian habitat. Extensive studies, including an Environmental Impact Statement, may be necessary to develop this alternative. Studies are necessary to determine if the site is geologically suitable or if seepage losses are unacceptable. Several diversions exist on the lower reaches of Big Lake Creek. Assuring that water will reach the point of use requires significant monitoring and maintenance.

7.5 Alternative 5: Big Swamp Creek, Upper Site

General Description: This alternative involves creating a reservoir on Big Swamp Creek by constructing a dam at a location one mile above the confluence with Slag-a-Melt Creek. Water backs up behind the dam and forms a reservoir within the natural floodplain. The Big Swamp Creek watershed above the diversion fills the reservoir and water discharges back into Big Swamp Creek.

Surface Area: Approximately 60 acres.

Capacity: Approximately 700 acre-ft.

Inflow and Outflow: Flow into the reservoir is via the natural watershed above this site. Flow out of the reservoir is directly into Big Swamp Creek.

Water Management And Conveyance to Point Of Use: This alternative increases the flow in Big Swamp Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical reach.

Advantages: No ditch construction is necessary. The site topography is favorable for constructing a dam using relatively low material quantities.

Disadvantages: The site size is limited and the watershed above this site is relatively small compared to other alternatives. Studies are necessary to determine if the site is geologically suitable or if seepage losses are unacceptable. Large swamps and several diversions exist on the lower reaches of Big Swamp Creek. Loss of water to groundwater greatly reduces the effectiveness of this alternative. Assuring that water will reach the point of use requires significant monitoring and maintenance.

7.6 Alternative 6: Big Swamp Creek, Lower Site

General Description: This alternative involves creating a reservoir on Big Swamp Creek by constructing a dam at a location just below the confluence with Slag-a-Melt Creek. Water backs up behind the dam and forms a reservoir within the natural floodplain. The Big Swamp Creek and Slag-a-Melt Creek watersheds above the dam fill the reservoir and discharge is back into Big Swamp Creek.

Surface Area: Approximately 70 acres.

Capacity: Approximately 1,500 acre-ft.

Inflow and Outflow: Flow into the reservoir is via the natural watersheds above this site. Flow out of the reservoir is directly into Big Swamp Creek.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Big Swamp Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical grayling reach.

Advantages: No ditch construction is necessary. Two watersheds with multiple lakes in their upper basins serve this alternative, so the water supply is relatively stable. The site topography is favorable for constructing a dam using relatively low material quantities.

Disadvantages: There are serious environmental impacts to existing wetlands and riparian habitat. Extensive studies, including an Environmental Impact Statement are necessary to develop this alternative. Studies are necessary to determine if the site is geologically suitable, if seepage losses are acceptable. Large swamps and several diversions exist on the lower reaches of Big Swamp Creek. Loss of water to groundwater greatly reduces the effectiveness of this alternative. Assuring that water will reach the critical grayling reach requires significant monitoring and management.

7.7 Alternative 7: Gravelle Creek Site

General Description: This alternative involves a new off-channel impoundment below Gravelle Creek to serve as a holding reservoir. Little Lake Creek and Miner Creek fill the reservoir which discharges back into Little Lake Creek.

Surface Area: Approximately 80 acres.

Capacity: Approximately 1600 acre-ft.

Inflow and Outflow: Flow into the reservoir is via diversions and lined ditches from Little Lake Creek and Miner Creek. Flow out of the reservoir is conveyed to Little Lake Creek by a lined ditch.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Little Lake Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical grayling reach.

Advantages: The system is off-channel, which reduces environmental impacts and sediment concerns. Two of the larger Upper Big Hole tributary watersheds provide water, which increases the likelihood for attaining 1,200 acre-ft of water on a consistent annual basis.

Disadvantages: Construction involves significant earthwork to build the reservoir and ditches. Water temperature in the holding reservoir is a concern during late summer. Several diversions exist on the lower reaches of Little Lake Creek. Assuring that water will reach the critical grayling reach requires significant monitoring and management.

7.8 Alternative 8: Miner Lake

General Description: This alternative involves raising the level and increasing the storage within Lower Miner Lakes by constructing a dam between the two lake segments. The upper Miner Creek watershed fills the reservoir and Lower Miner Lakes discharge back into Miner Creek.

Surface Area: Approximately 100 acres.

Capacity: Approximately 3000 acre-ft.

Inflow and Outflow: Flow into the reservoir is via the natural watershed above Lower Miner Lakes. Flow out of the reservoir is directly into Miner Creek.

Water Management and Conveyance to Point Of Use: This alternative increases the flow in Miner Creek. Downstream water monitoring and management are important to assure delivery of this water to the Big Hole River critical reach.

Advantages: No ditch construction is necessary. The site has ample capacity for current and future needs. The campground and existing road can be preserved with few modifications necessary after the dam is constructed. Miner Creek is within a relatively large tributary watershed with numerous lakes found in the upper basins, which increases the likelihood for attaining 1,200 acre-ft of water on a consistent annual basis.

Disadvantages: Extensive studies, including an Environmental Impact Statement, may be necessary to develop this alternative. Studies are needed to determine the rate of sedimentation, if the site is geologically suitable, and if seepage losses are acceptable. The natural character of Lower Miner Lakes is altered by this alternative. Several diversions exist on the lower reaches of Miner Creek. Relative to other alternatives, this alternative delivers water to the Big Hole River at a point further upstream. Assuring that water will reach the critical grayling reach requires significant monitoring and management.

7.9 Alternative 9: East Side Holding Reservoir

General Description: This alternative involves constructing an impoundment east of Highway 278 as a holding reservoir for Big Hole River water.

Surface Area: Approximately 80 acres.

Capacity: Approximately 1600 acre-ft.

Inflow and Outflow: Water is pumped from the Big Hole River and conveyed via pipeline to the holding reservoir. Water is returned to the Big Hole River via the same pipeline.

Water Management and Conveyance to Point Of Use: This alternative directly increases the upper Big Hole River flow. Downstream water monitoring and management are important to assure delivery of this water to the critical grayling reach.

Advantages: The pump station can be configured to pump during peak flows or during other time periods (including the winter months) so this alternative is less dependent on the peak flow. Water is directly returned into the Big Hole River without being channeled through diversions. Sedimentation within the holding reservoir can be kept to a minimum.

Disadvantages: Reservoir construction involves significant earthwork to shape the site. Because this alternative involves a mechanical pump station, continuous operations and maintenance is needed. The operating cost is dependent upon energy costs. Water temperature in the holding reservoir is a concern during late summer. Several diversions exist on the upper Big Hole River. Assuring that water stored by this means will reach the critical grayling reach requires significant monitoring and management.

8. ALTERNATIVES ELIMINATED FROM FURTHER CONSIDERATION

As a result of discussions at the TAC meeting several alternatives which underwent preliminary screening were eliminated from further consideration. A "fatal flaw" (an attribute which in the opinion of the advisory group and the Portage team rendered the alternative technically or legally unsound) was identified in each case of alternative elimination.

Alternative 1, the Schultz Reservoir system, was eliminated from further consideration due to concerns regarding the water yield of the sub-basin. Several members of the TAC felt that the drainage area was too small above the Shultz system to provide the required yield to fill an expanded reservoir system. An additional concern over private land conflicts was expressed and several TAC members expressed concerns over the relative complexity of the expanded Shultz Reservoir concept. Construction, operation and maintenance of this system would be relatively complex because of the three-reservoir concept and construction of a new lined ditch.

Alternative 3, the Twin Lakes site was eliminated from further consideration because of special status species concerns and because of the recreational value of Twin Lakes. The presence of boreal toad, a species of special concern as identified by the Montana Natural Heritage Program (MNHP) and the Montana Fish Wildlife and Parks (MFWP), has been verified in the shallows of Twin Lakes (USFS, 2000). The boreal toad is classified as S2 or "At risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state (MNHP, 2004)."

Because the site is located on lands administered by a federal agency, analysis of constructing a reservoir on Twin Lakes would likely require completion of an EIS by extension of the Environmental Policy Act (NEPA). Under NEPA analysis it is reasonable to expect that major impacts to Boreal Toad habitat would occur should a reservoir be constructed on Twin Lakes.

Although not identified in state or federal lists of special status species, Twin Lakes is known to hold an artic remnant strain of native lake trout. Significant lake trout population declines have been observed in Twin Lakes through MFWP sampling programs (USFS, 2000). The glacial remnant population is native, one of only two such populations in the state, and one of only four isolated native populations in the Continental United States. Elk Lake in the Madison Ranger District contains the second Montana population. The cause of this decline in lake trout numbers is speculative and although the species is unclassified it is reasonable to expect that NEPA analysis would conclude potential major impacts to the lake trout.

Additionally there are established recreation facilities at Twin Lakes including campgrounds and seasonal use cabins that would be highly impacted by inundation if a reservoir was constructed at the Twin Lakes site. The recreational value of these facilities would be lost and it is reasonable to expect that under NEPA analysis major impacts to recreational and visual resources would be identified.

Alternative 7, the Gravelle Creek Site was eliminated from further consideration because of its similarities to the Dry Creek Site. Of the two off-channel storage concepts, the Dry Creek Site was considered superior due to it's proximity to the critical reach. Also, the two design concepts are almost identical and scoping level cost estimates would be very similar.

Alternative 9, the East Side Holding Reservoir, was eliminated from further consideration because of concerns over cost and relatively intensive maintenance. A large pump would be required to fill this reservoir and energy costs would be very high. For example, a pump capable of delivering 1,000 gallons per minute to a 1,200 acre-foot capacity reservoir would fill the reservoir in 39 days not accounting for water losses. A pump capable of delivering this magnitude of flow 24 hours per day/seven days per week would be high horsepower and very expensive to operate. Maintenance of the other infrastructure required under this alternative (flow control instrumentation, pipelines, valves, weirs) would also be intensive compared to the other reservoir concepts.

9. CONCEPTUAL DESIGN AND COST FOR REMAINING ALTERNATIVES

Five sites were agreed upon by the TAC and the Portage team for further evaluation including development of a conceptual design and development of costs for alternative implementation. The conceptual design for each site includes plan view and cross sections of the dam and earthwork at each site in relation to site topography. The earthwork volumes and resultant reservoir capacities were calculated and refined over the acreages presented in preliminary site screening. In all scenarios, the required volumes were developed by considering a safety factor and minimum reservoir pool. The objective of the conceptual design is to develop a reservoir which yields optimized storage costs while efficiently utilizing surrounding landforms and topography. In keeping with the concept of a small, low maintenance, low operating cost and low public safety risk reservoir, the dam crest elevations are less than 50 feet above ground surface for all alternatives.

The remaining five alternatives are:

- Dry Creek
- Lower Big Lake Creek
- Big Swamp Creek
- Lower Miner Lake
- Small Seepage Sites

The “small seepage sites” design concept was not initially included in the preliminary site screening, but with the support of the TAC, the Portage team agreed that this alternative warranted further investigation. The design is based upon small acreage in close proximity to the Big Hole River and fed by springs or other flowing artesian groundwater. The potential exists for landowner cooperation in developing this type of storage site. The Upper and Lower Big Swamp Creek sites were combined for costing purposes per recommendation of the TAC. During the cost benefit analysis it soon became apparent that this alternative was high cost. In response, the Portage team detailed the cost of the Upper Big Swamp Creek site as the lower cost alternative of the two.

Costs were estimated for reservoir construction and operation at each remaining alternative. These estimates include real property transactions, permitting, engineering, earthwork, inlet works, outlet works, spillway, instrumentation, and operation and maintenance costs. Costs for earthwork are generally calculated by applying unit costs for cubic yards of cut and fill while unit costs for mechanical items were generally estimated as lump sum. Labor is included in all cost estimates.

Each estimate of cost provides a total capital cost, an annual operation and maintenance cost, and the cost of storage expressed as 2005 dollars per acre-ft of storage. Storage volumes for the cost analysis are based on the conceptual design of the remaining activities and generally show an increase from the volumes predicted in the preliminary analysis (Section 2). These increases account for design issues such as evaporation losses, minimum pool maintenance, and safety factors. The volume calculations rely on USGS topography and are calculated by cross section. Detailed site surveying and design refinements are likely to yield modified volume estimates.

The storage cost incorporates total estimated capital costs and operation and maintenance costs. For the purpose of the comparison, two numbers are given. The 30-year storage cost is the cost estimate that amortizes the capital cost over a 30 year period (the maximum period over which conventional financing would be arranged) and includes annual operation and maintenance costs. The storage cost after 30 years only considers the cost of annual operation and maintenance. *Table 9-1, Reservoir Storage Alternatives Cost Summary*, summarizes the estimated cost of each alternative.

Table 9-1. Reservoir Storage Alternatives Cost Summary

Alternative	**Capital Cost ($)**	**O&M Cost ($)**	**30-Year Cost ($ per Acre-ft)**	**Cost post 30-Year ($ per Acre-ft)**
Dry Creek	8.1M	22K	299	13
Lower Big Lake Creek	2.6M	17K	63	6
Big Swamp Creek (both sites)	6.3M	34K	177	15
Big Swamp Creek (upper only)	1.6M	17K	151	23
Lower Miner Lake	2.0M	17K	62	8
Small Seepage Sites	184K	2.3K	129	23

The following sections provide details and discussion of the five remaining alternatives. The detailed cost tables and cost benefit calculations are provided in *Appendix B, Reservoir Storage Alternatives Cost Estimates*.

9.1 Dry Creek

The Dry Creek Site alternative consists of a manmade off-channel storage impoundment located near the Ajax Ranch within the Dry Creek drainage. Water is diverted from Rock Creek and Big Lake Creek at two separate subsurface inlet structures and transmitted to the reservoir via buried pipe. The reservoir is filled throughout the year by the two inlets.

The impoundment consists of a 40-acre (at full pool) reservoir partially embedded into the slope, with a varying height dam surrounding four sides. The maximum height is 48 feet and minimum height is 22 feet above existing ground. The homogeneous earth dam structure is lined on the upstream sides with a clay blanket to minimize seepage. Subsurface gravel and pipe drains remove excess groundwater from beneath the dam to maintain stability. Excess groundwater is discharged into Big Lake Creek and an overflow spillway prevents water from overtopping the embankments should the inflow exceed outflow. Overflow water discharges via a surface ditch to Big Lake Creek.

The outlet works consist of twin pipes and gate valves that are accessed through a concrete vault positioned at the upstream side of the dam crest. Discharged water is transmitted through both pipes to a single larger pipe, buried downstream of the dam. The water emerges from the buried pipe at a controlled discharge point within Big Lake Creek. Although normally operated at a lower flow rate, the outlet is capable of discharging water to a maximum rate of 100 cfs.

The Dry Creek site is the highest cost of all five alternatives analyzed with an estimated capital cost of 8.1 million dollars and a cost/benefit of $299 per acre-foot for the first 30 years of storage. The high cost is directly proportionate to the amount of earthwork that would be required to construct this site. Extensive excavation below grade would be required below grade in addition to constructing a larger dam. The gross excavation required is approximately 900,000 cubic yards which would be balanced by placing and compacting the excavated material as embankment. Annual operation and maintenance costs would also be high due to new ditch maintenance and multiple inlet works.

The Dry Creek Site however, has the considerable advantage of water collection from two streams fed by a 52 sq. mi. watershed area. The inlets can be operated year around at minimal flow rates, which would diminish impacts to irrigators. Environmental impacts to existing streams are minimal and sediment accumulation in the reservoir can be highly controlled. It is anticipated that water temperature in the 60-ft deep pool can be maintained within the acceptable range for supporting arctic grayling. Upon receiving funding, this alternative could potentially be implemented in a shorter time period than alternatives sited on federal lands. *Figure 9-1, Dry Creek Conceptual Design* shows the conceptual plan view of the Dry Creek Reservoir.

Figure 9-1

9.2 Lower Big Lake Creek

The Lower Big Lake Creek alternative consists of impounding water above a dam on Big Lake Creek, a tributary to the Big Hole River. The site is located at the Hirschey diversion, approximately four miles below Twin Lakes and two miles upstream from the USFS boundary.

At this site, water is impounded by a zoned earth filled dam. The dam is constructed of on-site general fill materials with imported clay forming an impermeable core. A toe berm and drain are installed at the base of the downstream embankment. The reservoir inlet consists of the natural stream channel modified by a small sediment catch basin. A spillway, designed to handle significant flood flows, circumvents the dam to protect the embankment from overtopping.

The outlet works consist of twin pipes and gate valves that are accessed through a concrete vault positioned at the upstream side of the dam crest. Although normally operated at a lower flow rates, the outlet is capable of discharging water at a rate of 250 cfs.

Lower Big Lake Creek is one of two sites analyzed with a cost/benefit of under $100 per acre-foot for the first 30 years of storage. Capital costs are also low at an estimated 2.6 million dollars. The low cost of this site is due to the relatively small amount of earthwork required to impound the storage volume needed. Local ground topography at the site is amenable to low cost construction of a small reservoir. *Figure 9-2, Big Lake Creek Conceptual Design* shows the plan view of the Big Lake Creek Reservoir.

Figure 9-2

9.3 Big Swamp Creek

The Big Swamp Creek alternative consists of a two on-stream reservoirs within the Big Swamp Creek, tributary to the Big Hole River. The lower site is below the confluence of Slag-a-melt Creek and the upper site is approximately one mile upstream on Big Swamp Creek.

At each site, water is impounded by a zoned earth filled dam. The dams are constructed of on-site general fill materials with imported clay forming the impermeable core. A toe berm and drain are installed at the base of each downstream embankment. The reservoir inlet consists of the natural stream channel modified by a small sediment catch basin. Spillways, designed to handle significant flood flows, circumvent each dam to protect the embankments from overtopping.

At each dam, the outlet works consist of twin pipes and gate valves that are accessed through a concrete vault positioned at the upstream side of the dam crest. Although normally operated at a lower flow rates, each outlet is capable of discharging water to a rate exceeding 250 cfs.

The cost/benefit of developing both reservoir sites on Big Swamp Creek is relatively low at $177 per acre-foot of storage. Under this alternative the operating costs are doubled because of the management and maintenance costs of two individual reservoirs. The lower site requires a significant amount of embankment which yields the second highest capital cost of all the alternatives considered. If the upper site were developed alone, capital costs are relatively low at approximately 1.6 million dollars because the location of the dam is in very favorable topography. The amount of water impounded however is estimated to be less than other sites yielding a relatively low cost benefit of $151 per acre-foot. Figure 9-3, Big Swamp Creek Conceptual Design shows a plan vies of the Upper and Lower Big Swamp Creek Reservoirs.

Figure 9-3

9.4 Lower Miner Lake

The Lower Miner Lake alternative consists of increasing Lower Miner Lake to greater than twice its original surface area. Lower Miner Lake is found on Miner Creek, a tributary to the Big Hole River, within the Beaverhead Mountains west of Jackson, Montana. The lake is located approximately four miles upstream from the USFS boundary.

The existing lake has a natural peninsula that separates upper and lower portions of the lake. In this alternative, the dam spans the narrows between the peninsula and higher ground on the opposite side. The dam is a zoned earth filled dam. It is constructed of on-site general fill materials with imported clay forming an impermeable core. A toe berm is installed at the base of the downstream embankment.

The reservoir inlet consists of the natural stream channel modified by a small sediment catch basin. A spillway, designed to handle significant flood flows, traverses the existing peninsula to protect the embankment from overtopping. The outlet works consist of twin pipes and gate valves that are accessed through a concrete vault positioned at the upstream side of the dam crest. Although normally operated at a lower flow rates, the outlet is capable of discharging water at a rate of 280 cfs.

The Lower Miner Lake site is one of two sites analyzed with a cost/benefit of under $100 per acre-foot for the first 30 years of storage. Capital costs are also low at an estimated 2 million dollars. The low cost of this site is due to the relatively small amount of earthwork required to impound the storage volume needed. The natural topographic bottleneck at the outlet to the lake is amenable to low cost construction of a small dam. The estimated storage is less than that at Lower Big Lake Creek yielding a cost/benefit almost identical to that site in spite of lower capital costs. *Figure 9-4, Lower Miner Lake Conceptual Design* shows the plan view of the Lower Miner Lake Reservoir.

Figure 9-4

9.5 Small Seepage Sites

This alternative consists of impounding water produced by natural springs and seeps located in close proximity to the Big Hole River. The springs/seeps are developed to fill a holding pond, and water is released into the Big Hole River from the pond via an outlet pipe and ditch. A typical impoundment consists of a 10-acre (at full pool) reservoir partially embedded into the slope, with a varying height dam surrounding four sides. The maximum embankment height is 15 feet above existing ground. An overflow spillway prevents water from overtopping the embankments, should the inflow exceed outflow. Overflow water discharges via a surface ditch to the Big Hole River.

The outlet works consist of a single pipe and gate valve that are accessed through a concrete vault positioned at the upstream side of the dam crest. The outlet is capable of discharging water at a rate exceeding 100 cfs.

The small seepage site conceptual design is based on a private land holding where springs feed a shallow marshy area. The example site is in close proximity to the main stem of the Big Hole River and has the advantage of potential continual discharge to the Big Hole from the existing springs. The capital cost of developing this site is relatively low at an estimated $184,000. Because the amount of storage gained is also relatively low at approximately 100 acre-feet, the cost of the storage is relatively high at $129 per acre-feet. Cost calculations for this conceptual design were performed by pricing an excavator/dozer team with a known production rate. Hourly rates for equipment were verified locally. *Figure 9-5, Small Seepage Site Conceptual Design* shows the small seepage site plan view.

Figure 9-5

10. RECOMMENDATIONS FOR SITE SPECIFIC STUDY

This section presents site specific recommendations for advancing each alternative that underwent conceptual design. Further investigation at Lower Big Lake Creek and Lower Miner Lake is recommended for on-channel storage. Recommendations for the Upper Big Swamp Creek site are presented as an alternative to Lower Big Lake Creek. Recommendations are also presented for the Small Seepage Sites Alternative. Recommendations for further analysis of Dry Creek and the Lower Big Swamp Creek site are not presented because of the high cost of these alternatives.

Recommendations for future work are based on a phased approach to managing the progression of implementing a reservoir storage alternative. Phase 1 is the work product of the *Reservoir Storage and Water Management Review* project and the recommendations for site specific study presented herein would constitute Phase 2. The Portage team envisions a logical sequence of steps for completion of a reservoir storage project as follows.

- ***Phase 1*** – identify suitable sites, analyze feasibility, conceptual design, budget level cost estimates, and recommendations.

- ***Phase 2*** – Perform appropriate level of environmental analysis for geotechnical investigation on USFS land sites, surveying and mapping of recommended sites, geotechnical investigation of recommended sites, and refine recommendations, conceptual design and cost estimates based on new data.

- ***Phase 3*** – Perform appropriate level of environmental analysis and environmental permitting for reservoir construction, secure rights/agreement for intended use of water, complete reservoir design, prepare construction bid documents, and refine construction and operation and maintenance cost estimates based on new data.

- ***Phase 4*** – Bid reservoir construction project, construct reservoir, and commission reservoir.

The work of Phase 2 would primarily consist of field geologic, hydrogeologic, and geotechnical investigations coupled with necessary environmental analysis. Detailed site surveying would also be performed. These field investigations are necessary to confirm site feasibility, refine capital cost estimates and site conceptual designs, and to refine site specific recommendations.

Phase 2 Field Investigations: The purpose of the geotechnical/geological investigation is to collect, interpret, and report geological/geotechnical information relevant to constructing water storage alternatives for the Big Hole Water Storage project. A geotechnical/geological investigation typically includes development of a testing plan, implementing field surveys, collecting samples, testing representative materials, interpreting test results, and developing engineering recommendations.

The testing plan would show the location of boreholes and trenches, quantify sample collection and analysis, and detail any environmental mitigations required. Environmental mitigations typically include measures to control the introduction of noxious weeds, measures to control the introduction of petroleum fluids to the environment, and measures to reclaim land disturbances.

Field surveying involves an assessment of onsite soils and rocks, bedrock, stratigraphy, groundwater and seeps, topography, and other existing conditions that affect engineering design. Typically, such an investigation includes exploration drilling involving standard penetration tests and the collection of soil/rock samples. Test pits are excavated to provide visual confirmation of subsurface conditions and to collect larger bulk soil and rock samples for testing. Sites that pose difficult access for wheeled vehicles can be investigated by using a track-mounted drill rig and/or excavator.

Soil and rock samples are tested for their physical, engineering, and hydraulic properties. Both *in situ* properties of onsite soils and the engineering properties of potential construction materials are of interest to the investigation. Engineering design constraints and economic decisions are based on onsite material properties.

Existing groundwater levels, observed seepage flow rates, and field tests are assessed to support water balance calculations and seepage predictions. Piezometers, or shallow groundwater observation wells, are installed during site drilling to provide a means to measure and test groundwater flow characteristics.

Upon completion of the field investigation and laboratory tests, design recommendations can be developed. If fatal flaws are identified over the course of the geological/geotechnical investigation, no further consideration will be given to the affected alternative. If the site is determined to be suitable for development, the conceptual design and preliminary construction cost estimates can be updated to reflect existing conditions and earth materials suitability/availability.

Detailed site surveying would be required in order to accurately model the site and refine volume calculations. Earthwork quantities, dam dimensions and other basic design factors which drive cost would also be refined. A detailed site survey is an important step in verifying the conceptual design and site specific cost estimates in addition to providing the topographic data used in detailed engineering design.

Phase 2 Environmental Analysis: It is expected that Phase 2 field investigation environmental analysis for sites located on lands managed by the USFS would include obtaining special use permits and/or performing an environmental assessment (EA) of the impacts of geotechnical drilling. The purpose of the EA is to evaluate the degree of positive and/or adverse effects on the environment. These impacts or effects potentially include localized adverse effects to vegetation and soils so that drilling equipment could access the investigation area. Other potential impacts requiring analysis may include impacts to wetlands, impacts to steep slopes and highly erosive soils, impacts the migration and or breeding habitat of sensitive species such as the lynx or northern goshawk, and impacts to inventoried roadless area values. Each effect and any required mitigation would be characterized in the environmental analysis.

On USFS lands the minimum level of environmental analysis for proposed actions is a categorical exclusion or CE. The test of a CE is whether or not a “routine action” action will have a “significant effect” on a resource or value listed as an “extraordinary circumstance” in the *USFS Environmental Policy and Procedures Handbook, 1910.15, Chapter 30*. The handbook lists “geophysical exploration” as a routine activity the may be categorically excluded with a decision memo, but in the case of Lower Miner Lake and Lower Big Lake Creek extraordinary circumstances may apply. These extraordinary circumstances include inventoried roadless areas, wetlands, and floodplains.

If the action is determined to adversely affect a resource or value for which there are extraordinary circumstances an EA would likely be required. Because the Lower Miner Lake and Lower Big Lake Creek sites are adjacent to inventoried roadless areas, it may be determined that the impacts of a geotechnical investigation will have adverse affects on roadless values and resources. For example, if significant lodgepole pine was planned to be cleared for exploration drill rig access, the cleared area may adversely affect the scenic value and integrity of the landscape.

There are opportunities in developing the site investigation plans for minimizing potential environmental impacts and effects. These opportunities include using equipment with low ground-pressure to limit damage to vegetation and soils; using routes of entry which avoid wetlands and other sensitive areas; and avoiding steep slopes which may be susceptible to erosion damage. Public support of a project also has a dramatic impact on the success of a public lands project and on the rigor and timeliness of environmental analysis. For these reasons the Portage team recommends an approach to designing field investigation plans which includes the following steps.

1. Organize a legal organization or entity as the project "owner" and responsible party for the proposed action.

2. Perform initial field visits with USFS personnel and other critical parties (BHWC TAC, agricultural community, environmental conservation leaders and others) to view the sites, discuss issues, and to begin mapping sensitive environmental areas within the region of interest.

3. Draft site specific field investigation plans which include routes of entry, borehole/trench and other sampling locations, best management practices for erosion control and noxious weed control, sensitive area avoidance and other proposed mitigation measures, and other applicable environmental controls.

4. Solicit the support of local environmental conservationists and other public citizens for the proposed action through the BHWC, BHRF, and through other communications.

5. Revise field investigation plans based on comments from the USFS and other interested parties to insure minimization of environmental impacts under the proposed action.

6. Submit the field investigation action plan to USFS for decision on appropriate level of environmental analysis under NEPA.

7. Perform one analysis for all sites considered in the field investigation phase with multiple findings and decisions under the EA or CE.

The Portage team believes that public and agency support of the proposed action (from the field geotechnical investigation phase to the construction phase) is critical in successful and timely NEPA compliance. A stepwise approach that earns this support is recommended.

10.1 Dry Creek

The greatest disadvantage of the Dry Creek site is its substantial capital cost. Due to these high costs, a Phase II evaluation of this alternative is not recommended at this time. However, if grant monies or other relief from the financial burden could be secured, the Dry Creek alternative is recommended because of the substantial drainage area available to feed the reservoir; the ability to control environmental impacts such as sedimentation; fewer impacts to irrigators; and, the potential reduction in project duration gained by locating the project on private lands.

10.2 Lower Big Lake Creek

Lower big Lake Creek is recommended for Phase 2 evaluation because of its low capital cost and high cost-benefit. The site topography is advantageous for construction of a small dam and discharge to the main-stem of the Big Hole River through Big Lake Creek is relatively near the grayling critical reach. On channel construction will help moderate reservoir heating and thermal stratification. The Lower Big Lake

Creek site is also considered in this study as a potential managed wetland, potentially yielding competing recommendations. *Table 10-1, Lower Big Lake Creek Phase II Cost Estimate* shows estimated costs (labor, equipment, and travel) for the components of a Phase 2 investigation of the Lower Big Lake Creek site.

Table 10-1. Lower Big Lake Creek Phase II Cost Estimate

Task	**Task Total**
Project Management • Contracting • Bidding • Environmental planning • Reports and presentations	$3,000
Surveying and Mapping • Professional engineering labor • Surveying labor and CADD services • Mileage • Per-diem • Lodging • Equipment and supplies	$12,000
Basin Hydrology and Stream Hydraulics Analysis • Professional engineering labor • Hydrogeologist labor • Geologist/fluvial geomorphologist labor • Water rights consulting • GIS services • Mileage • Per-diem • Lodging	$29,000
Site Permit(s) for Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Surveying labor and CADD services	$16,000

Table 10-1. Lower Big Lake Creek Phase II Cost Estimate Cont.

Geological and Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • Materials and field supplies • Mileage • Per-diem • Lodging • Drilling services, equipment and labor • Piezometers, installed cost • Hydrologic tests, field and laboratory • Geotechnical laboratory testing	$48,000
Presentations, Written Reports, and Recommendations • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • GIS specialist • Mileage • Per-diem • Lodging	$11,000
In-Kind Services • Professional engineering labor • Environmental engineering/NEPA specialist labor • Mileage	$5,000
Net Cost (Grand Total minus In-Kind Services)	***$119,000***

10.3 Big Swamp Creek

The Upper Big Swamp Creek site is recommended as an alternative to Lower Big Lake Creek for Phase II evaluation. The site is located within favorable topography and the overall capital cost is low at approximately $1.5M. Because this site does not have the storage potential of Lower Big Lake Creek, the cost-benefit is significantly lower than the Lower Big Lake Creek site. Detailed surveying may show opportunity for greater storage capacity with minimal escalation of estimated capital cost. Discharge to the main-stem of the Big Hole River through Big Swamp Creek is relatively near the grayling critical reach.

Because of the high capital cost, relatively low cost-benefit and relative complexity of the combined Upper and Lower Big Swamp Creek alternatives, Phase II evaluation is not recommended. *Table 10-2,* *Upper Big Swamp Creek Phase II Cost Estimate* shows estimated costs (labor, equipment, and travel) for the components of a Phase 2 investigation of the Upper Big Swamp Creek site.

Table 10-2. Upper Big Swamp Creek Phase II Cost Estimate

Task	**Task Total**
Project Management • Contracting • Bidding • Environmental planning • Reports and presentations	$3,000
Surveying and Mapping • Professional engineering labor • Surveying labor and CADD services • Mileage • Per-diem • Lodging • Equipment and supplies	$6,000
Basin Hydrology and Stream Hydraulics Analysis • Professional engineering labor • Hydrogeologist labor • Geologist/fluvial geomorphologist labor • Water rights consulting • GIS services • Mileage • Per-diem • Lodging	$23,000
Site Permit(s) for Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Surveying labor and CADD services	$14,000

Table 10-2. Upper Big Swamp Creek Phase II Cost Estimate Cont.

Geological and Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • Materials and field supplies • Mileage • Per-diem • Lodging • Drilling services, equipment and labor • Piezometers, installed cost • Hydrologic tests, field and laboratory • Geotechnical laboratory testing	$34,000
Presentations, Written Reports, and Recommendations • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • GIS specialist • Mileage • Per-diem • Lodging	$11,000
In-Kind Services • Professional engineering labor • Environmental engineering/NEPA specialist labor • Mileage	$5,000
Net Cost (Grand Total minus In-Kind Services)	***$91,000***

10.4 Lower Miner Lake

Lower Miner Lake is recommended for Phase II evaluation because of its low capital cost and high cost-benefit. The site topography is advantageous for construction of a small dam and the potential exits to expand or enhance an existing recreation facility. Discharge to the main-stem of the Big Hole River through Miner Lake Creek is further up-river of the grayling critical reach compared to other recommended alternatives. On channel construction will help moderate reservoir heating and thermal stratification. *Table 10-3, Lower Miner Lake Phase II Cost Estimate* shows estimated costs (labor, equipment, and travel) for the components of a Phase 2 investigation of the Lower Miner Lake site.

Table 10-3. Lower Miner Lake Phase II Cost Estimate

Task	Task Total
Project Management • Contracting • Bidding • Environmental planning • Reports and presentations	$3,000
Surveying and Mapping • Professional engineering labor • Surveying labor and CADD services • Mileage • Per-diem • Lodging • Equipment and supplies	$13,000
Basin Hydrology and Stream Hydraulics Analysis • Professional engineering labor • Hydrogeologist labor • Geologist/fluvial geomorphologist labor • Water rights consulting • GIS services • Mileage • Per-diem • Lodging	$29,000
Site Permit(s) for Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Surveying labor and CADD services	$14,000

Table 10-3. Lower Miner Lake Phase II Cost Estimate Cont.

Geological and Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • Materials and field supplies • Mileage • Per-diem • Lodging • Drilling services, equipment and labor • Piezometers, installed cost • Hydrologic tests, field and laboratory • Geotechnical laboratory testing	$48,000
Presentations, Written Reports, and Recommendations • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • GIS specialist • Mileage • Per-diem • Lodging	$11,000
In-Kind Services • Professional engineering labor • Environmental engineering/NEPA specialist labor • Mileage	$5,000
Net Cost (Grand Total minus In-Kind Services)	***$118,000***

10.5 Small Seepage Sites

The Small Seepage Sites alternative is recommended because of the possibility of landowner participation, low capital, operation, and maintenance costs, and the possibility of utilizing a constant spring discharge to the Big Hole River more efficiently. Although some environmental permitting may be required to implement this alternative, none would be required to perform the limited hydrogeological and geotechnical field investigation required to confirm the viability of this alternative. *Table 10-4, Small Seepage Sites Phase II Cost Estimate* shows estimated costs (labor, equipment, and travel) for the components of a Phase 2 investigation of the Small Seepage site.

Table 10-4. Small Seepage Sites Phase II Cost Estimate

Task	Task Total
Project Management • Contracting • Bidding • Environmental planning • Reports and presentations	$2,000
Surveying and Mapping • Professional engineering labor • Surveying labor and CADD services • Mileage • Per-diem • Lodging • Equipment and supplies	$3,000
Hydrogeological and Geotechnical Investigation • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • Materials and field supplies • Mileage • Per-diem • Lodging • Drilling services, equipment and labor • Piezometers, installed cost • Hydrologic tests, field and laboratory • Geotechnical laboratory testing	$12,000
Presentations, Written Reports, and Recommendations • Professional engineering labor • Environmental engineering/NEPA specialist labor • Geologist/fluvial geomorphologist labor • Hydrogeologist labor • GIS specialist • Mileage • Per-diem • Lodging	$2,000

Table 10-4. Small Seepage Sites Phase II Cost Estimate Cont.

In-Kind Services • Professional engineering labor • Environmental engineering/NEPA specialist labor • Mileage	$1,000
Net Cost (Grand Total minus In-Kind Services)	***$19,000***

11. CONCLUSIONS

In conclusion, both Lower Miner Lake and Lower Big Lake Creek are recommended as candidate sites for Phase 2 investigation because of site suitability and the low cost of storage. Upper Big Swamp Creek is recommended as an alternative because of low capital cost of reservoir construction and site suitability. Detailed surveying may show additional reservoir capacity and greater cost benefit at this site. The Small Seepage Site concept is also recommended as a candidate for Phase 2 investigation because of its low capital cost, ease of implementation, and opportunity for landowner participation. The Dry Creek site is not recommended because of the high cost of implementation, but the site may be a feasible alternative if capital cost and funding were of less concern.

A phased approach to implementation is recommended should the reservoir storage concept be pursued further. Phase 2 would include development of a field investigation plan for geotechnical, geological, and hydrological work at selected sites. All necessary field and laboratory work required to complete a detailed engineering design and construction bid package would be collected during this phase. Detailed site surveying would also be completed. For sites located on USFS lands, proposed plans for geotechnical field investigations would be subject to NEPA and an appropriate level of environmental analysis would be performed prior to the work. Public project support and USFS support of the proposed action is critical to successful and timely NEPA compliance. Detailed field investigation plans that are designed to minimize environmental impacts and protect public resources are also critical for project advancement. An approach which solicits public support through the BHWC at the initiation of Phase 2 is recommended.

Appendix A

Reservoir Storage Alternatives Summary Matrix

Appendix B

Reservoir Storage Alternatives Cost Estimates

Appendix C

Comparison Table of All Analyzed Storage and Other Water Management Alternatives