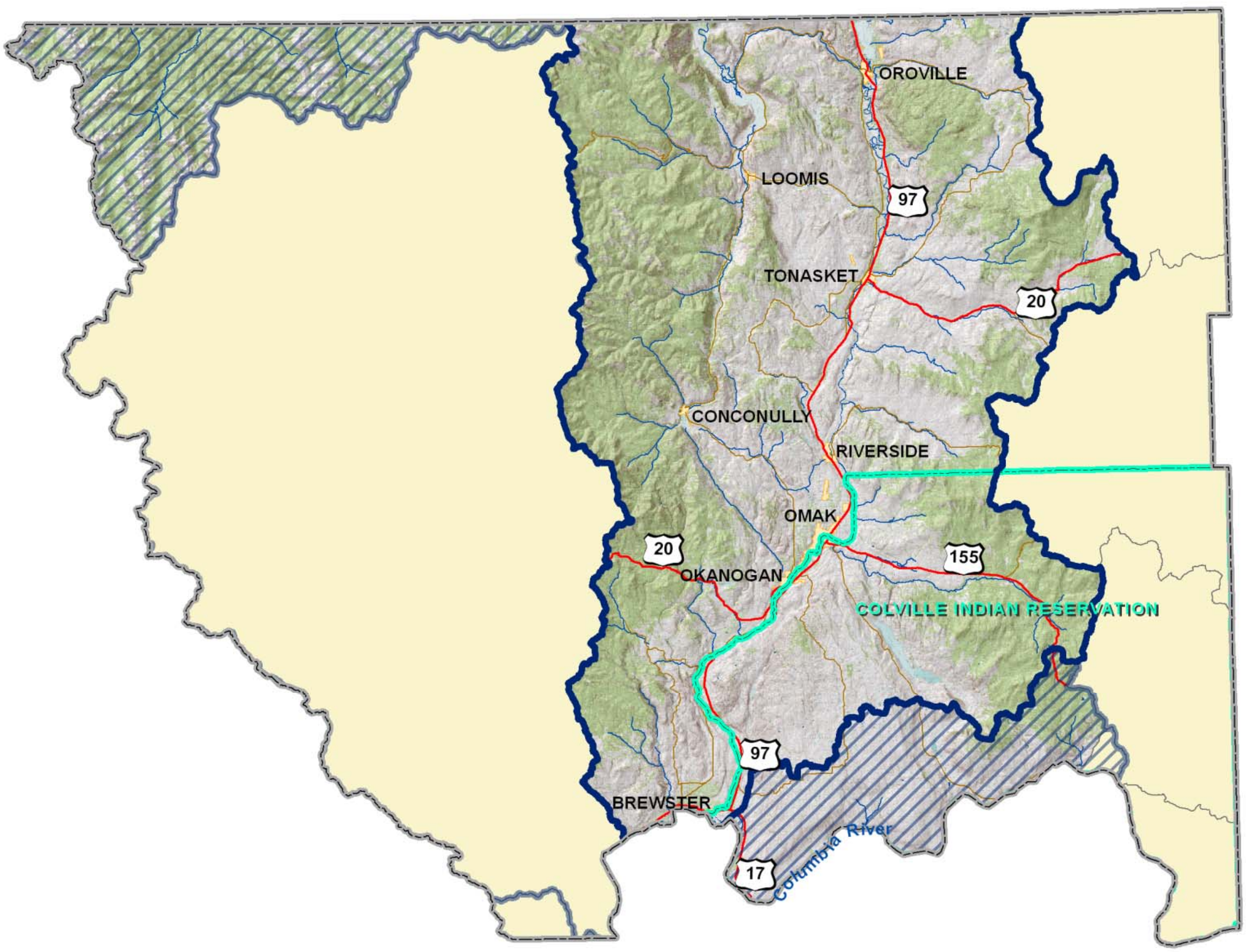
OKANOGAN WATERSHED PLAN

Water Storage Assessment



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WRIA 49 Water Storage Assessment

FINAL Report

Prepared for:
Okanogan Watershed Planning Unit

March, 2009

MWH

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1.0 INTRODUCTION AND BACKGROUND

In response to the WRIA 49 Level 1 Watershed Technical Assessment (ENTRIX, 2006), a recommendation was made to further identify and assess potential storage opportunities in the WRIA 49 Okanogan River Basin in the United States. This document describes the investigation to identify storage opportunities in WRIA 49 and recommends possible projects for further study.

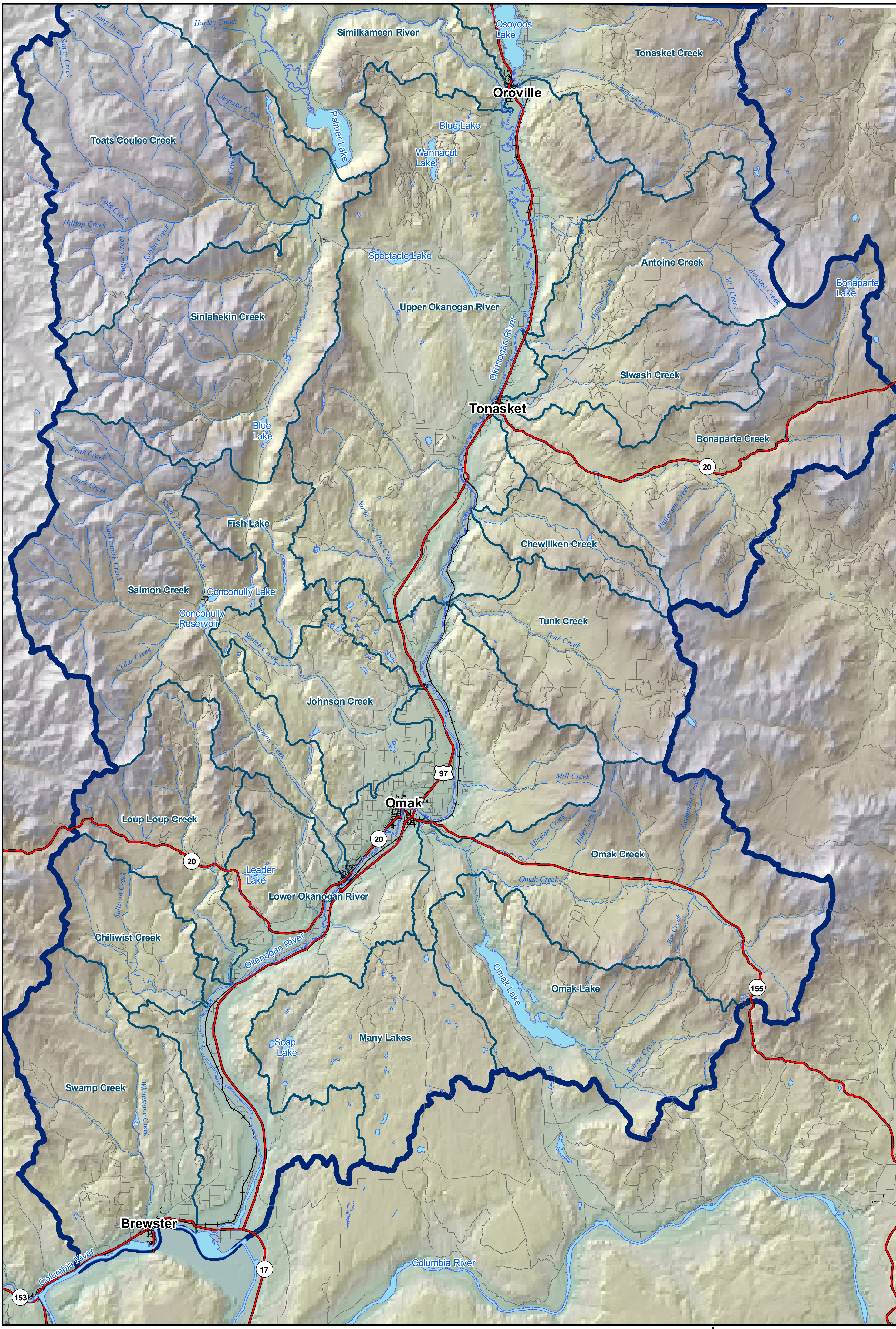
The objective of the study was to review historical data, identify new surface and ground water storage opportunities within WRIA 49, and to develop estimates of benefits, potential constraints, and the qualitative effects on a water balance for each project. The intent is not to recommend development of specific storage projects, but instead to identify projects that may warrant further study.

As part of this analysis, a compilation of current and historic studies was developed. The reports of these studies were read and data from possible storage sites were recorded. Potential surface water, groundwater, and aquifer storage projects in the Okanogan watershed were identified. A field reconnaissance trip was taken to view the possible sites that were identified. The sites were evaluated at a reconnaissance level of analysis, and a qualitative estimate of how these projects would affect the water balance of its subbasin was developed. Potential constraints for each project, such as available water quantity, dam and structure size, possible location issues, and geotechnical issues were identified given the available data and information.

This document relies on data and analyses from other reports and sources, especially the WRIA 49 Level 1 Technical Assessment (ENTRIX, 2006). While numerical values are reported to help quantify project size and impact, these values are preliminary and approximate. For example, much of the data on dam height, storage capacity, and crest length were taken from USGS quadrangle sheets with forty-foot contour intervals. Many storage opportunities have dams less than this contour interval. Much additional data still need to be collected to properly size and evaluate the feasibility of any individual project. All values reported in this report should be considered preliminary and approximate given this reconnaissance level of investigation.

The Okanogan River Watershed encompasses approximately 8,900 square miles (mi^2), including 6,300 mi^2 in British Columbia and 2,600 mi^2 in Washington. The headwaters are in British Columbia, about 110 miles north of the boundary between Canada and the United States. The Okanogan River discharges into the Columbia River about 79 miles south of the international boundary at an elevation of 780 feet. The mean annual precipitation in the United States ranges from 11 inches per year at lower elevations to 30 inches per year at higher elevations.

For this report, subbasins within WRIA 49 were designated by the local stream name rather than the region names used in the WRIA 49 Level 1 Assessment (ENTRIX, 2006). Figure 1-1 shows a map of WRIA 49 area, the Okanogan River basin in Washington, and the subbasins used in this study. For each stream, on which a project was identified, the tributary subbasin was designated. Small tributaries without projects that also drain directly into the Okanogan River were aggregated into larger subbasins. Storage site identifications in this study are also designated by these subbasins.



Legend

- Highway
- Road
- Town Road
- Rail Road
- Rivers & Streams
- Lakes
- WRIA 49 Basin
- WRIA 49 Subbasins

WRIA 49 Watershed and Subbasins

0 1 2 4 6 8 Miles

WRIA 49 Water Storage Assessment

1:300,000 Scale

Spatial Reference: UTM Zone 11N, NAD-83

N

Figure 1-1

MWH

WRIA 49 Watershed and Subbasins

2.0 SUMMARY OF CURRENT AND HISTORIC DATA

Table 2-1 summarizes water storage projects previously considered in the Okanogan watershed. For each project, the table lists the project name and available data on the type, volume, size, source, purpose, use, location, timeframe, and fate of the proposed project.

Data for the table was gathered from review of reports from CH2M Hill Northwest, Inc., 1979, 1991, J. Pratt *et al.*, 1999, Northwest Hydraulic Consultants Inc., 1985, US Army Corps of Engineers, 1982, 1984, International Joint Commission, 1955, and Hatch Energy, 2008.

Additional data was obtained through interviews conducted with the following people:

Affiliation	Name
Okanogan Conservation District	Bob Clark, Craig Nelson
City of Oroville	Chris Branch
Okanogan County	Brad Scott
Colville Confederated Tribes	Dolores Castillo
Highlands Associates	Kurt Danison
Okanogan Irrigation District	John Bartella
Oroville Tonasket Irrigation District	Tom Scott
Whitestone Irrigation District	Jerry Barnes
City of Okanogan	Chris Johnson
Chelan County Public Utility District	Julie Pyper

The 46 listed water storage projects include 31 surface water storage, 11 surface pumped storage, 3 interbasin transfers of surface water and 2 aquifer recharge (groundwater storage) projects. Often, a series of alternative storage volumes or project configurations have been considered at the same site (e.g., high, medium and low dam concepts at Shanker's Bend on the Similkameen River); these are each reported as a separate project.

Most of the projects were small to medium sized; of the 46, two had less than 1,000 ac-ft active storage; 13 were between 1,000 and 10,000 ac-ft; 14 were 10,000 to 100,000 ac-ft; eight were between 100,000 and 1,000,000 ac-ft; and 3 were greater than 1,000,000 ac-ft No data on storage volume were available for six of the projects. The smallest project identified was a 500 ac-ft surface water storage project on the West Fork of Salmon Creek, the largest a 4.7 M ac-ft pumped storage project at Goose Flats.

Projects have been proposed throughout the past century, ranging from a 1919 Chopaka Lake proposal to the current investigation of projects at Shanker's Bend on the Similkameen River.

Nineteen of the 46 proposals were for surface water storage projects on the Similkameen River. Four projects were proposed on Sinlahekin Creek, and three each on Palmer Lake and the Ashnola River.

Many proposals were projects dedicated to water storage, but multipurpose projects serving irrigation, hydropower, and flood control as well as in-stream water values such as improved fish flows have also been proposed.

Cost estimates, where available, reflect economic data current at the time the project was proposed and have not been converted into current year dollars.

Some indication of the evaluation of the project was obtained for 30 of the 46 projects. Projects were not carried forward for a variety of reasons, including high capital and operating costs, low storage potential, poor geotechnical conditions for dam construction, ecological conflicts including conflicts with anadromous fish, impacts to landowners, and other environmental concerns.

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Aquifer Storage and Recovery, 1999	Aquifer/ Ground Water Storage	5,100 acre-ft	Watercress Springs	Recovery project	Lower Salmon Creek between Watercress Springs and the Okanogan city limits	Dames & Moore	1999	▪ Recovery at 5,100 acre-ft/ year ▪ Total est. cost $2.5M (in 1999 dollars)	Eliminated due to uncertainty of groundwater resource
Ashnola River No. 1, 1955	Surface Water Storage	47,500 acre-ft	Ashnola River	Water storage	19 miles above its confluence with the Similkameen River	International Joint Commission	1955		
Ashnola River No. 2, 1955	Surface Water Storage	22,100 acre-ft	Ashnola River	Water storage	One mile below McBride Creek	International Joint Commission	1955		
Ashnola River No. 3, 1955	Surface Water Storage	30,000 acre-ft	Ashnola River	Water storage	1-1/2 miles below Wall Creek	International Joint Commission	1955		
Blue Lake Dam	Surface Water Storage	1,340 ft long, 33 ft high, storage 6,800 acre-ft	Sinlahekin canal	No data	No data	No data	prior to 1923	▪ Cost $70,644.90 (in 1923 dollars) ▪ Built on a foundation of glacial grave, and the water seeped through the gravel	Built in 1923. In 1932 there was enough water flow to fill the Blue Lake Dam and it was discovered that the Dam would not hold water. Attempts to repair it were futile and the Dam was abandoned. By 1934 the Sinlahekin canal washed out to the point it was not feasible to repair it, and all water deliveries from Sinlahekin ceased. However spring runoff water into Blue Lake acts as a ground water recharge for Sinlahekin Creek to help maintain an all summer flow for irrigators and fish in the valley

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Bromley 1955 High Dam	Surface Water Storage	400,000 acre-ft	Similkameen River	Water storage	13 mile downstream from Princeton	International Joint Commission	1955	▪ Earth –fill dam	
Bromley 1955 Low Dam	Surface Water Storage	50,000 acre-ft	Similkameen River	Water storage	13 mile downstream from Princeton	International Joint Commission	1955	▪ Earth –fill dam	
Brown Lake, 1999	Pumped Storage	Estimated at 10,000 acre-ft	Salmon creek	Water would be pumped from Salmon Creek into Brown Lake	0.5 miles above Green Lake, and about 2.5 miles above the point at which Green Lake is tributary to Salmon creek.	Dames & Moore (See page 4-51 for location)	1999	▪ Total est. cost $7.3M (in 1999 dollars)	Carried in to phase 2 but was dropped due to high cost
CCT Reservation, 1999	Ground Water Storage	5,100 acre-ft being recharged	No data	Joint study of Salmon Creek	9 miles from Salmon Creek	Dames & Moore (See page 4-53 for more information)	1999	▪ Est. cost $2.5M (in 1999 dollars)	This study concluded that groundwater recharge would be infeasible in the lower Salmon Creek sub-basin
Chopaka Lake, 1919	Surface Water Storage	10,000 acre-ft	Toats Coulee around Quartz Mountain	No data	Chopaka Lake	WRD	1919		Never built due to economics and not a very practical idea
Chopaka Lake, Low Dam, 1920	Surface Water Storage	Less than 10,000 acre-ft	Nine Mile Creek	Store irrigation water	Chopaka Lake	WRD	1920		Built in 1921, the ditch hasn't run water since the 1970s and the Whitestone Reclamation District relinquished all interest in Chopaka Lake in the '70s
Chopaka Lake, 1979	Pumped Storage	9,300 to 39,000 acre-ft	Palmer Lake	Water storage Hydropower Flood control	Chopaka Lake	CH2M Hill	1979	▪ Water would be pumped 8,000ft from Palmer Lake and lift 1,900ft into Chopaka Lake	Physically possible and worth future study
Fish Lake, 1999	Interbasin transfer	No data	Salmon creek Gibson and Spikeman Creeks Unnamed springs	No data	2 miles north of Salmon Creek	Dames & Moore	1999		Eliminated due to cost of pumping to Conconully Lake (previously called Salmon Lake)
Goose Flats, 1977, 2009	Pumped Storage	7,000 to 4,725,000 acre-ft	Okanogan and Columbia Rivers	Water storage Hydropower	No data	Pacific Northwest River Basin Commission, Dept of Ecology	1977, Present	Storage at Goose Flats, located outside of WRIA 49 between Omak Lake and the Columbia River, is being studied as part of the Dept. of Ecology's Columbia Basin Initiative.	Current study is at pre-appraisal phase, however, due to its location it is unlikely that this project would provide benefits for WRIA 49 water users.

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Green Lake, 1999	Surface Water Storage	5000 acre-ft	Green lake	Produce additional water for the restoration of Conconully Lake.	1 mile north of Salmon Creek	Dames & Moore	1999		Eliminated for impacts to scenic, wetlands, and recreation
Horse Spring Coulee, 1923	Surface Water Storage	2,000 acre-ft	No data	Irrigation, water storage	No data	No data	1923	▪ Built on a foundation of glacial grave, and the water seeped through the gravel	Completed in 1925. Filling went smoothly to 10 or 12 ft about 2,000 acre-ft then pool started to drop each day no matter how much water was added This project was abandoned
Johnson Creek 1999	Interbasin transfer	No data	Salmon creek	No data	Johnson Creek	Dames & Moore	1999		No additional water available
Lenton Flats, 1979	Pumped Storage	226,000 acre-ft	Similkameen River	Water storage Hydropower Flood control	Downstream of where the Similkameen enters the U.S	CH2M Hill	1979		Eliminated from further consideration due to high capital and operating costs and low storage potential. Potential future project component- not a stand alone project
Nighthawk 1, 1955	Surface Water Storage	31,900 acre-ft	Similkameen River	Water storage	Similkameen River RM 12.0	International Joint Commission	1955		
Nighthawk 2, 1955	Surface Water Storage	52,600 acre-ft	Similkameen River	Water storage	Similkameen River RM 14.4	International Joint Commission	1955		
Nighthawk 3, 1955	Surface Water Storage	106,000 acre-ft	Similkameen River	Water storage	Similkameen River RM 15.8	International Joint Commission	1955		
Omak Lake, 1977	Pumped Storage	1,200,000 to 3,655,000 acre-ft	Okanogan and Columbia Rivers	Water storage Hydropower	No data	Pacific Northwest River Basin Commission	1977		

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Palmer Lake, 1955	Surface Water Storage	Storage 30,000 acre-ft	Sinlahekin River	Possibility of adding a 15 feet high earth dam to provide and additional 30,000 acre-ft	North end of Palmer Lake	International Joint Commission	1955		
Palmer Lake, 1979 High Lift	Pumped Storage	Control elevation at 1,148 ft, add 25,500 acre-ft storage	Palmer Lake	Increase water storage at Palmer Lake	Palmer Lake with the canal	CH2M Hill	1979	▪ Pumped from the lake into a canal with bottom elevation at 1,148.5 ft ▪ Est. construction cost $3,510,000 (in 1979 dollars) ▪ Would only provide marginal storage benefits compared to options located at Shanker's Bend	
Palmer Lake, 1979 Low Lift	Pumped Storage	Control elevation at 1,148 ft, add 25,000 acre-ft storage	Palmer Lake	Increase water storage at Palmer Lake	Palmer Lake with the canal	CH2M Hill	1979	▪ Pumped from the lake into a canal with bottom elevation at 1,140 ft ▪ Est. construction cost $3,450,000 (in 1979 dollars) ▪ Would only provide marginal storage benefits compared to options located at Shanker's Bend	
Palmer Lake, 1979 No pumping	Surface Water Storage	Control lake elevation at 1,150.4 ft, add 13,100 acre-ft storage	Spring flooding of the Similkameen River and Sinlahekin Creek	Increase water storage at Palmer Lake	Palmer Lake with the canal	CH2M Hill	1979	▪ Using a discharge-feeder canal and three radial gates placed in the canal to regulate flow. ▪ Est. construction cost $3,540,000 (in 1979 dollars) ▪ Would only provide marginal storage benefits compared to options located at Shanker's Bend	

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Palmer Lake Storage Project, 1990/ 1991	Surface Water Storage	Estimated 10,500 acre-ft	Similkameen River	Water storage	Existing Chopaka Road Bridge 1 mile north of Palmer Lake	CH2M Hill for Oroville-Tonsket Irrigation District	1990/ 1991	▪ Still represents a potential storage option, but would not provide any hydropower benefit ▪ Would only provide marginal storage benefits compared to options located at Shanker's Bend	On May, 1991, the State determined, that OTID had not demonstrated a "need" for the Palmer Lake Project. Between June and September, 1991, OTID withdrew its request for federal funds, anticipating that this Project would not succeed in winning these limited funds.
Pasayten Wilderness, 1979	Surface Water Storage	213,000 acre-ft	No data	No data	Up in Pasayten Wilderness	CH2M Hill	1979		Would provide the Public Utility District with a reliable major power and it is worth further study
Railroad Bridge Site, 1984 (Small Dam)	Surface Water Storage	Max. pool elevation 965 ft, top of dam 975 ft, storage 3,100 acre-ft	Similkameen River	Multipurpose project providing storage for flood control, irrigation, and downstream power generation	Similkameen River RM 6.6	USACE	1984	▪ Feasibility Study ▪ RCC dam ▪ Construction cost $30,000,000 (in 1984 dollars)	Project abandoned due to conflict with anadromous fish habitat below Enloe dam
Railroad Bridge Site, 1984 (Alternative Pool Elevations)	Surface Water Storage	Pool elevation 1,145 ft	Similkameen River	Multipurpose project providing storage for flood control, irrigation, and downstream power generation	Similkameen River RM 6.6	USACE	1984		Project abandoned due to conflict with anadromous fish habitat below Enloe dam
Railroad Bridge Site, 1985 (Alternative High Dam	Surface Water Storage	Max. pool elevation 1,155 ft, storage 100,000 acre-ft	Similkameen River	Multipurpose project providing storage for flood control, irrigation, and downstream power generation	Similkameen River RM 6.6	USACE, assisted by Northwest Hydraulic Consultants	1985	▪ Feasibility Study ▪ Construction cost $106,000,000 (in 1984 dollars)	Project abandoned due to conflict with anadromous fish habitat below Enloe dam
Richter Lake, B.C, 1979	Pumped Storage	Max. pool elevation 2,000 ft, storage 140,000 acre-ft	Similkameen River and a 4.5-mile-long penstock	Water storage and an irrigation reservoir	12 miles northwest of Oroville, B.C.	CH2M Hill	1979		Physically possible and worth future study
Richter Lake, B.C, 1979 Smaller Dam & Reservior	Pumped Storage	Max. pool elevation 1,800 ft, storage 40,000 acre-ft	Similkameen River and a 4.5-mile-long penstock	Water storage and an irrigation reservoir	12 miles northwest of Oroville, B.C.	CH2M Hill	1979		Physically possible and worth future study

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Salmon Creek, 1999 Phase II	Surface Water Storage	3 Projects	No data	Identify several water storage opportunities	No data	Dames & Moore	1999		Identified three feasible projects
Raise Salmon Lake Dam and Replace Feeder Canal, 1999	Surface Water Storage	660 to 990 acre-ft	No data	To raise Salmon Creek by 2ft so additional winter runoff could be captured	Conconully Lake (previously called Salmon Lake)	Dames & Moore (see page 4-54)	1999	▪ Total est. cost $2.1M (in 1999 dollars)	Eliminated due to inability to provide sufficient water
Scotch Basin, 1999	Pumped Storage	10,000 acre-ft of new storage	Scotch Creek and Coulee Creek	No data	5.7 miles downstream of Concounlly	Dames & Moore	1999		Eliminated due to landownership, high scenic quality, and local opposition
Scotch Creek, 1999	Interbasin transfer	No data	Johnson creek Duck Lake	No data	Scotch Creek	Dames & Moore	1999		No additional water available
Shanker's Bend High Dam, 1948, 1972, 1995, 1979, 2008 ongoing	Surface Water Storage	Max. water surface elevation 1,289 ft, 1.3 million acre-ft active storage	Similkameen River	Potential water storage along the similkameen River. Maintain adequate spills and min. flows downstream on the Columbia River Flood control, reservoir for irrigation and other uses.	Shanker's Bend RM 6.9	USACE(1948, 1972) International Joint Commission(1955) CH2M Hill (1979) Okanogan PUD(2008 on going)	1948, 1972, 1955, 1979, 2008	▪ Earth- or rock-fill ▪ Will flood Indian lands in B.C. ▪ Flood control benefits	Under consideration by Ecology and Okanogan PUD
Shanker's Bend Low Dam, 1955, 1972, 2008 ongoing	Surface Water Storage	Max. water surface elevation 1,155 ft, 20,000 acre-ft active storage	Similkameen River	To maintain water level in Palmer Lake below flood level, avoid flooding around Palmer Lake Hydropower, Irrigation, Flood control	Shanker's Bend RM 6.9	International Joint Commission (1955) USACE (1972) Okanogan PUD (2008 ongoing)	1955, 1972, 2008	▪ Concrete gravity structure ▪ Potential constraint: any dam developed at this location would impact the ability to develop other storage projects on the Similkameen River or Sinlahekin Creek near Palmer Lake	Under consideration by Ecology and Okanogan PUD

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

Project	Type	Total volume/ size	Water Source	Anticipated use/ Purpose	Location	Proponent/ Reference	Time period proposed/ studied	Note	Fate
Shanker's Bend Site, 1984	Surface Water Storage	Max. pool elevation 1,150 ft, top of dam at 1,160 ft, storage approx. 30,000 acre-ft	Similkameen River	Flood control, hydro power	Near the existing railroad bridge (about 2 miles below Enloe Dam)	USACE	1984	▪ Feasibility Study ▪ Roller-compacted concrete (RCC) dam with an site powerhouse ▪ Will flood Native American land ▪ Construction cost $118,000,000 (in 1984 dollars)	Indicated that a multipurpose project on the Similkameen River would have the potential of meeting existing or projected flood control, irrigation, hydropower needs of Okanogan County.
Shanker's Bend, 1987	Surface Water Storage	Max. pool elevation 1,155 ft, total active storage 106,867 acre-ft	Similkameen River	Multipurpose feasibility study on flood control benefits	On the Similkameen at the railroad site	USACE	1987		
Shanker's Bend Medium Dam, 2008 ongoing	Surface Water Storage	Max. water surface elevation 1,175 ft, 138,000 acre-ft active storage	Similkameen River	Max. operating reservoir water surface to keep the reservoir pool within the United States Hydropower, Irrigation, Flood control	Shanker's Bend RM 6.9	Okanogan PUD	2008	▪ Concrete gravity structure	Under consideration by Ecology and Okanogan PUD
Similkameen #3, 1955, 2008	Surface Water Storage	164,000 acre-ft storage	Similkameen River	Flood control, water supply, ecological flow improvements and hydroelectric power development	13 miles downstream from Princeton, B.C.	International Joint Commission (1955) Hatch Energy (2008)	1955, 2008	▪ Recommended development of a hydroelectric facility at this location	1955- Not considered due to economics? 2008- Still under review
Sinlahekin Creek Project, 1979	Surface Water Storage	Max. pool elevation of 1,200 ft, max. storage 23,000 acre-ft	Sinlahekin Creek	Store water during high flow periods in Sinlahekin Creek, release water during the summer and fall.	Across Sinlahekin valley near Palmer Lake, 11 miles southwest of Oroville.	CH2M Hill	1979	▪ 60ft high	
West Fork Salmon Creek	Surface Water Storage	500 acre-ft potential firm yeild	No data	Water storage	No data	Dames & Moore	1999		Eliminated as no feasible storage site was identified
Zosel Dam, 1979	Surface Water Storage	No data	Okanogan River	Provide more storage	Outlet of Osoyoos Lake	CH2M Hill	1979		Dam was replaced - Completed in 1987 see http://hqweb.unep.org/dams/documents/ell.asp?story_id=145

Table 2-1: Matrix of historic studies and projects evaluating storage in WRIA 49

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3.0 FIELD VISIT

3.1. Trip Summary

A field visit to prospective sites was conducted on August 20-21, 2008. The team conducting the site visit consisted of a civil engineer, a water resources engineer, a geotechnical engineer, and a hydrogeologist, all from MWH. On-the-ground reconnaissance evaluations of both surface and groundwater storage sites were conducted. For surface storage sites, general observations of local topography led to an assessment of probable design features, including alignment of the dam, potential type of dam, and maximum potential height. A geotechnical assessment evaluation of suitability of the foundation was made based on the surface geology and soils observed. The quantity of farm and housing relocations that would be necessary was estimated. The length of roads that need to be relocated and the difficulty of relocating the road around a potential dam were also considered. Observations of the stream channel geometry and riparian vegetation levels were made to provide a very rough estimate of how much runoff might be present at the site. Finally, an assessment of the availability of nearby materials for construction was made.

For potential groundwater storage sites, field reconnaissance included site visits and general observations within the Okanogan River watershed from Oroville, near the Canadian border, to the Columbia River and included the major tributary drainages to the Okanogan River. Site reconnaissance activities included visual observations of the various basins and subbasins, general soil and rock conditions, rock outcrops, relative soil depths, topography upstream of dams (to assess possible dam heights and therefore relative storage capacities), width of subbasin alluvial floors, potential sources for recharge water, and other factors which might affect the viability of managed aquifer recharge.

A summary of field reconnaissance observations for surface and groundwater sites is provided in Appendix A.

3.2. General Observations

The Okanogan River Basin is a glaciated watershed, in which the geomorphological characteristics are largely a result of glacial lobes that extended southward into what is now the Okanogan Valley. Extensive surface deposits originated largely from glacial till and outwash/alluvium. Bedrock underlying the sediments is composed of granitic and andesitic rocks, metamorphosed sedimentary rocks, and basalts. The basalt flows represent the northern extension of the Columbia River Basalts. Pleistocene glacial activity carved the valley’s general morphology and the rounded exposures of bedrock in parts of the valley. The valley fill consists of Pleistocene glacial deposits (till and outwash), as well as Holocene (recent) alluvial and fluvial deposits.

Soils in the Okanogan Basin are formed from volcanic ash and pumice, glacial till, glacial outwash, alluvial deposits, lake sediments, and loess (wind-deposited silts). In general, soils in the northern part of the basin and in the upper subbasins are dominantly fine-grained, including silt, clay, and fine sand, often with gravel and in some cases cobbly material distributed through the matrix (NRCS 1979).

Aquifers in the Okanogan Basin occur within the glacial and alluvial deposits in the valley lowlands and larger tributary subbasins. Well depths range from 20 feet to over 200 feet and most groundwater production occurs in the upper 150 feet or less. Wells often yield 300 gallong per minute (gpm) or more in the Okanogan River Valley where coarse alluvial and glacial outwash sediments form more productive aquifers, but wells along the valley margins and within the subbasins are typically much less productive (WDOE 1999). Wells in the Okanogan River Valley tend to have higher rates of production potential in the southern part of the valley than in the northern part (WDOE 2008).

Surface storage opportunities would appear to be the greatest in the low-lying areas along the Okanogan River floodplain or its major tributary, the Similkameen River, due to larger expanses of relatively flat terrain that would provide high storage to height ratios. Agricultural development, wetlands, or cities in these areas, however, would preclude the development of surface storage facilities in these locations. At the edges of the Okanogan River floodplain, the terrain becomes steep and rocky before flattening once again. A difference in the terrain of upper reaches of tributaries varies depending on geographic location in the particular tributary valley. On the east side of the valley, the terrain remains moderately sloped until rising into mountains in the tributary head waters. On the west side of the valley, the terrain is significantly steeper and continually gains elevation up to head waters in the North Cascade Mountains.

4.0 POTENTIAL STORAGE OPPORTUNITIES

Surface storage sites within WRIA 49 were initially developed using topographic mapping and a survey of watershed drainage areas. Well logs, geologic mapping, and previous reports were used to identify potential groundwater storage locations. Additional sites were identified in correspondence with Okanogan Conservation District and by study of available data. Figure 4-1 shows the locations of all surface storage sites that were initially considered for storage, and Figure 4-6 shows the groundwater sites considered in this study.

Of these, analysis of feasibility and storage potential has identified nine surface storage locations, in 6 subbasins, and 2 groundwater storage areas, that are considered the most feasible and may warrant future study. Much additional analysis is still required to assess the actual feasibility of pursuing a storage project in any of these locations, including, but not limited to, hydrology studies, geotechnical investigations, water rights assessments and additional data collection. All values presented in this report should be considered approximate given a reconnaissance level of investigation. Table 4-1 below is a summary table of the most favorable locations. Their locations are shown on Figure 4-1.

Table 4-1: Summary of Potential Storage Projects.

ID	Description	Type	Estimated Max Storage (ac-ft)
SA1	Salmon Creek near Omak	Surface	3,300
JO1	Johnson Creek near Riverside	Surface	1,700
BP4	Bonaparte Creek near Aeneas Valley	Surface	2,100
BP6	Bonaparte Creek at Bonaparte Lake Road	Surface	950
BP7	Bonaparte Lake Raise	Surface	300
AN2	Antoine Creek in Antoine Valley	Surface	760
AN3	Antoine Creek at Fancher's Dam	Surface	900
SN1	Palmer Lake	Surface	10,500
SM1	Similkameen River	Surface	50,000-1.7M
GW5	Upper Antoine Creek	Groundwater	2,400
GW13	Lower Salmon Creek	Groundwater	3,000

4.1. Surface Storage Opportunities

Table 4-1 shows the possible storage sites by identification number, name, type of storage, and estimated maximum capacity. Nine surface storage opportunities, within six subbasins, have been identified to have potential for further analysis. Sites within the same subbasin indicate that multiple storage sites are possible within that subbasin. The capacity is estimated based on the topography of the site itself and a preliminary assessment of the water available to it. Water availability was based on interpolations from actual stream flow data from nearby stream gages. Other information provided in the following sections, such as precipitation, is present merely for comparison purposes and was not used for estimating storage. Further analysis is required to identify the best location for a water storage facility, based on further knowledge of the geology and water availability. This study only recommends that further analysis at these sites may be warranted, not that storage should be developed at these locations. The order in which the sites are presented is by geographic location in the watershed, south to north, and does not indicate that some sites have greater potential than others. See Table 4-2 for a summary of physical data for each surface storage opportunity.

4.1.1. Salmon Creek – SA1

As part of this investigation, an in-stream storage site was identified along the lower reaches of Salmon Creek near Green Lake. This is site SA1, which is described below.

4.1.1.1. Location and Site Characteristics

A potential site exists on Salmon Creek just upstream of Spring Coulee, close to where the channel from Green Lake enters Salmon Creek. At this location, topographic mapping shows that there is a small valley upstream of the dam site that could provide an opportunity for storage. A 30- to 40-foot high earth-fill dam could be constructed in this location that would span the valley and create a reservoir with a maximum surface area of approximately 135 acres. The crest length of the dam would be 700-900 feet and the potential storage capacity would be about 3,300 acre-feet. See Figure 4-2.

4.1.1.2. Water Source and Quantity

The watershed drainage area at the dam site is estimated to be 148 square miles and the watershed mean annual precipitation is estimated as 21 inches. The anticipated operation would be to capture high snowmelt flows during the spring and release them later in the year for either water supply or in-stream flow needs. A USGS gage was located just downstream of the potential site that recorded continuous flow data from 1904-1910. This data was used in conjunction with more recent information as, this data was recorded before the completion of Conconully Dam. Releases from Conconully Dam were obtained by the USGS for the time period from December 2002 to March 2006. Using these data, an annual volume of 37,600 acre-feet is estimated to pass the proposed dam site. From March through June, 3,200 acre-feet is estimated to pass the site, which may be available for storage in the potential reservoir. Additional data collection would be necessary to determine the water rights and usage in Salmon Creek at these times.

Table 4-2: Surface Storage Project Data

ID	Description	Dam Height (ft)	Dam Type	Res. Inundation (ac)	Crest Length (ft)	Tot. Est. Storage (ac-ft)
OM2	Omak Creek Upper	40	Earthfill	16	280	315
SA1	Salmon Creek near Omak	40	Earthfill	135	900	3,300
SA2	Salmon Creek US Conconully Reservoir	80	Arch / Concrete	58	515	1,700
JO1	Johnson Creek near Riverside	30	Earthfill	200	300	1,700
BP2	Bonaparte Creek near Bannon Creek	50	Earthfill	195	1,260	4,100
BP4	Bonaparte Creek near Aeneas Valley	70	Earthfill	76	615	2,100
BP5	Bonaparte Creek Upper	40	Earthfill	53	615	1,070
BP6	Bonapart Creek at Bonaparte Lake Road	50	Earthfill	40	740	950
BP7	Bonaparte Lake Raise	2	Earthfill	235	500	300
AN2	Antoine Creek in Antoine Valley	80	Earthfill/ Concrete	18	200	760
AN3	Antoine Creek at Fancher's Dam Road	20	Earthfill	58	850	900
SN1	Palmer Lake	30	Earthfill	2920	5,500	10,500
SN2	Sinlahekin Creek US of Loomis	100	Earthfill / Concrete	135	500	5,600
SN3	Sinlahekin Creek near Blue Lake	160	Arch / Concrete	14	575	800
TC1	Toats Creek near confluence with Sinlahekin	200	Concrete	32	800	2,400
TC2	Toats Creek North Fork	160	Concrete	18	850	975
SM1	Nighthawk	30	Earthfill	n/a	900	31,000

Note: All values reported are based on reconnaissance level of analysis and have wide error ranges. For the analysis of individual sites, topographic data was available at 40-foot contour intervals, runoff and continuous flow data was, in most cases, extremely limited, and dam type and height estimates were made based on limited geotechnical analysis and cursory observations of surface geology.

4.1.1.3. Potential Constraints

Agriculture and grazing lands within the inundation zone would need to be compensated or relocated. The greater issue with this site, however, is that the creek is not free flowing because of Conconully Dam, located upstream. Releases from the reservoir greatly impact the available flow in the river and a high percentage of potential spring flows that would otherwise be stored in this reservoir are already captured in Conconully Reservoir. However, it may be possible to operate this reservoir in coordination with Conconully Reservoir to obtain additional benefits.

Water rights on Salmon Creek may also be an issue. The WRIA 49 Level 1 Assessment shows that almost all streams within WRIA 49 are over-appropriated, and this may impact the ability to obtain a water right to capture, store, and release flows for other purposes. A dam at this site may still have value in substantiating existing water rights, however.

4.1.2. Johnson Creek – JO1

4.1.2.1. Location and Site Characteristics

Potential for storage in Johnson Creek exists in the downstream reaches just as the creek enters the Okanogan River floodplain. A small backwater structure appears to exist at the termination of Greenacres Road at Johnson Creek. This area presents a possible location for a larger storage structure because of the narrow river channel. A 20 to 30-foot high earthen or rock-fill dam could be constructed just upstream of the existing structure. The new dam would impound a reservoir of approximately 200 acres. See Figure 4-2. The crest length of the dam would be about 300 feet, and the potential storage capacity would be 1,700 acre-feet. In the upstream portion of the inundation area, a berm or saddle dam may need to be constructed to keep water from flowing into Duck Lake.

4.1.2.2. Water Source and Quantity

The watershed drainage area at the location of the dam is estimated at 68 square miles, and the watershed mean annual precipitation is estimated as 15 inches. A USGS gage was located on Johnson Creek near Riverside that recorded stream flows from 1903-1962. Using the average annual flow data from these records, an average annual volume of 3,615 acre-feet is estimated to pass the dam site, which would supply sufficient flows to fill the potential reservoir. The anticipated operation of the reservoir would be to capture high snowmelt flows during the spring and release them later in the year for either water supply or in-stream flow needs. Storage at this site would not detract from water rights but instead be used to secure existing rights by making water available at times when it is needed.

4.1.2.3. Potential Constraints

Agriculture and grazing lands within the inundation zone would need to be relocated. Monthly estimates of water usage and in-stream flow are needed to assess the potential volume of water available to be captured and stored in this reservoir. In addition, a summary of water rights on the river and the ability to obtain rights to store and release water at this location needs to be determined.

In the upstream reaches of reservoir, there is potential for water to seep or flow out of Johnson Creek and into Duck Lake, a terminal basin. Previous studies have shown that soils around Duck Lake have capacity for groundwater infiltration, indicating that soils in or near the potential reservoir could provide seepage out of the reservoir (Pratt, 1999). This project could be combined with a groundwater storage project. However, it is unclear if infiltration to ground-water can be quantified or put to beneficial use.

4.1.3. Bonaparte Creek – BP4, BP6, BP7

Bonaparte Creek offers a number of possible locations for storage, mostly in the upper reaches of the watershed. Lower reaches of the watershed are highly developed as agriculture or grazing lands, which would preclude the ability to develop storage. Three potential locations for storage in the upper reaches were identified. These sites have been designated as BP4, BP6, and BP7. See Figures 4-1 and 4-3. The anticipated operation of dams at all three locations would be to capture high flows in the spring for delivery down to Bonaparte Creek in the summer for irrigation on farms located further downstream.

4.1.3.1. Location and Site Characteristics

BP4:
The first site is located approximately 2 miles northeast of where the Bonaparte Creek drains into the Aeneas Valley. At this location, the creek opens into a relatively wide valley with moraine or esker deposits running along the left bank. Both right and left banks appear to be glacial outwash with granular soils at the surface, which would require treatment prior to storing water. An earth-fill dam up 70-feet high could be constructed at this location that would have a crest length of approximately 620 feet and inundate an area of 76 acres. The reservoir would have a capacity of about 2,100 acre-feet.

BP6:
The second site is located near the intersection of Highway 20 and Bonaparte Lake Road, just upstream of the confluence of the fork that drains from Bonaparte Lake into the main stem. At this location, rock outcroppings on both sides of the valley exist that would provide a good foundation for a dam, although some excavation of fractured rock would

still be required. In addition, a relatively wide, flat valley extends upstream from the dam site, providing an opportunity for storage. An earth-fill dam of approximately 50-80 feet high with a crest length of approximately 740 feet could be constructed at this location that would inundate a reservoir area of 40 acres. The reservoir would have a potential storage capacity of 930 acre-feet.

BP7:
The third possibility in the Bonaparte basin would be to raise the water level of Bonaparte Lake. An earth-fill dam approximately 500 feet in length could be constructed at the downstream end of the lake to raise the lake level. Insufficient topography data is available to accurately estimate the optimal lake raise, but 2-3 feet would likely be sufficient to capture excess flows at the outlet. A control structure at the reservoir outlet would allow for control of the lake level and release of flood waters. Spring high flows would be stored in the reservoir and released later in the summer. The raised reservoir could provide up to 300 acre-feet of additional storage. When full, the lake would inundate approximately 235 total acres, which is approximately 75 acres of additional inundation than the existing lake when full.

4.1.3.2. Water Source and Quantity

At BP4, the watershed drainage area at the location of the dam is estimated to be 58.5 square miles and the watershed mean annual precipitation is estimated as 20 inches. Using data from a USGS gage located at the downstream end of Bonaparte Creek, near Tonasket, it is estimated that 2,165 acre-feet of water passes the dam location annually. A dam 70-ft high would have a maximum potential storage capacity of 2,100 acre-feet. Flows may be underestimated in the upper reaches, however, because flow data from the gage near Tonasket is affected by upstream irrigation diversions. Since this analysis assumed flows would be available in proportion to the drainage area, and less irrigation occurs in the upstream reaches, more flow may be available than a proportional analysis indicates (Wilbur, 2008).

At BP6, the watershed drainage area at the location of the dam is estimated to be 26 square miles and the watershed mean annual precipitation is estimated as 20 inches. Using data from the same USGS gage located at the downstream end of Bonaparte Creek, it is estimated that 955 acre-feet of water pass the dam location annually. The potential storage in the reservoir is 950 acre-feet.

At BP7, the watershed drainage area is estimated as 6.5 square miles and the watershed mean annual precipitation is estimated as 20 inches. Using data from a USGS gage located at the downstream end of Bonaparte

Creek, near Tonasket, it is estimated that 240 acre-feet of water pass the dam location annually. It is likely that the actual runoff at this site is different than that derived from extrapolation from the gage located in the lower reaches of the valley. However, additional data collection at the site is necessary to determine runoff volumes and optimally size the reservoir.

4.1.3.3. Potential Constraints

BP4:
Highway 20, which runs along the river, would become inundated with the construction of a dam at this location. It was not clear during the site visit if a suitable route to relocate the road exists nearby. Water rights on the stream may be an issue due to existing rights on Bonaparte Creek. The WRIA 49 initial study (ENTRIX, 2006) shows that almost all streams in the Okanogan watershed are over-appropriated, which may impact the ability to capture, store, and release flows for other purposes. Bonaparte Creek is particularly developed with agriculture and grazing areas along most of the river. For construction of a dam at this location, several farms or houses located in the reservoir area would need to be relocated.

BP6:
The quantity of water available at the site may be an issue. Also, the inundation area is located in the Bonaparte Lake recreation area, which may make it more difficult to permit and may reduce the overall benefit of the project. Depending on height of the dam, several houses located in the reservoir area would need to be relocated. Bonaparte Lake Road would also have to be relocated, which may be difficult along the edges of the floodplain because of steep terrain.

BP7:
The total quantity of runoff at the location of the dam may not be sufficient to warrant the costs of construction at this location. It is possible that the existing structure may be able to capture the entire hydrograph during most years. Additional studies would need to be performed to assess if there is sufficient water supply, and to what height the water level in Bonaparte Lake could reasonably be raised without impacting surrounding facilities and significantly increasing the cost of the project.

4.1.4. Antoine Creek – AN2, AN3

In general, Antoine Creek is relatively flat in the lower reaches and highly developed with agriculture. The middle reaches have steep, rocky terrain that would provide little storage relative to the height of a dam that would be required. The upper reaches are relatively flat with abundant glacial outwash. Two sites were identified along the upper reaches of Antoine Creek that may provide potential storage opportunities. See Figure 4-4.

4.1.4.1. Location and Site Characteristics

AN2:
The first site on Antoine Creek is located approximately one mile upstream of the flat lower Antoine Valley. At this location, rock was observed on both abutments which may provide a solid foundation for a dam, although observation showed that the rock was fractured at the surface. The left and right abutments encroach onto the valley floor from each side in a manner that would be suitable to support a 60- to 80-foot high earth-fill or roller-compacted concrete (RCC) dam. The dam would have a crest length of approximately 200 feet and inundate a reservoir of approximately 18 acres. The total storage capacity in the reservoir is estimated to be 760 acre-feet. The valley floor may also be suitable source of core material for an earth fill dam.

AN3:
The second site is located at the existing Fancher's Dam, which is in the upper portion of the watershed at the confluence of Swanson Mill Road and Fancher Dam Road, near the town of Havillah. It appears that the existing dam could be raised by approximately 20 feet, creating a dam that is 50-60 feet high. The new crest length would be 850-feet long and the reservoir would inundate an area of approximately 58 acres. Analysis of the existing dam would be required to determine if it would provide a suitable base for a higher dam.

4.1.4.2. Water Source and Quantity

AN2:
The watershed drainage area at the location of the dam is estimated to be 48.5 square miles, and the watershed mean annual precipitation is estimated as 19 inches. No known continuous stream gages are present in the Antoine Creek basin, but, Antoine Creek and Bonaparte Creek have similar precipitation and other physical characteristics. Since capture in the reservoir takes place at times when irrigation diversions are low, it is likely that runoff and evapotranspiration patterns between the two creeks are also similar. Using runoff per unit area patterns from a USGS gage located at the downstream end of Bonaparte Creek near Tonasket, it is estimated that 1,800 acre-feet of water passes the AN2 site annually, which may be sufficient for the potential reservoir storage volume of 760 acre-feet.

Flow patterns in Antoine Creek are likely impacted by operation of the existing Fancher Dam upstream, which may capture a significant portion of the high spring flows that would otherwise reach this dam site. Coordination with Fancher Dam will be necessary in calculating the operation of this proposed dam. Similar to the other projects discussed in this report, water storage at sites along Antoine Creek would not detract from water rights but instead be used to firm up existing rights by making water available at times when it is needed.

AN3:
No known continuous stream gages are located nearby AN3. The watershed drainage area at the location of the dam and the watershed mean annual precipitation are estimated to be 34 square miles and 20 inches, respectively. Using runoff patterns from data on Bonaparte Creek, it is estimated that 1,260 acre-feet of water passes the dam location annually. The maximum potential reservoir storage volume is 900 acre-feet. Additional hydrologic studies are necessary to determine the actual yield.

4.1.4.3. Potential Constraints

AN2:
No water was present in the creek during our site visit in late August, 2008, leading to questions about whether sufficient flows pass this site to warrant construction of a dam. Land in the inundation zone is private and some may be used for agriculture. Access may also be an issue due to land ownership. Currently, the only access is from a local dirt road that runs along the west bank of the Antoine Creek for several miles before reaching the dam location.

AN3:
The left abutment appears to be sandy glacial drift, which may cause stability and seepage issues. On our site visit, no outlet works were found for the existing dam, suggesting the dam may be leaking or there is a submerged pipe that was not immediately visible. New outlet works would probably have to be built. Correspondence with Okanogan Conservation District has revealed that the water rights for the existing Fancher's Dam may already be over-appropriated. Water rights on the existing reservoir and land rights around the dam must be negotiated with the owner. Additional hydrological and water rights analyses would be required to determine if excess flows are sufficient to make a raised dam feasible.

4.1.5. Palmer Lake – SN1

Potential to add storage at Palmer Lake has been studied extensively in the past. The International Joint Commission (1955) evaluated the possibility of adding a 15-ft high earth dam at the north end of Palmer Lake to provide an additional 30,000 acre-feet of storage. CH2M Hill (1979) evaluated three pumped-storage options that would store varying amounts of spring flood flows from the Similkameen River in Palmer Lake and release them in the summer. CH2M Hill also studied the possibility of adding pumped-storage up to Chopaka Lake, although costs to pump and store in Chopaka Lake would make this alternative infeasible. Finally, in 1990, the Oroville-Tonasket Irrigation District (OTID) proposed to capture spring flood flows from the Simikameen or Sinlahekin in Palmer Lake by constructing a control channel adjacent to the existing Chopaka Lake Bridge, located one mile north of Palmer Lake (CH2M Hill, 1990).

4.1.5.1. Location and Site Characteristics

While larger storage alternatives may be possible, the most promising alternative, from a cost and permitting standpoint, would be to develop storage at Palmer Lake by limiting the lake raise to the height of the existing flood level, similar to the project proposed by OTID in 1990. The project would include construction of a concrete control structure along the south side of Chopaka Road above Palmer Creek. See Figure 4-5. An earth-fill dam would be constructed to contain the additional water within Palmer Lake, which would be approximately 5 feet high and 5500 feet long. Two control gates would be added that would allow spring flood waters from the Similkameen River to flow into Palmer Lake. Water stored in the lake would come from diverted flows from the Similkameen River or inflows from Sinlahekin Creek. The resulting lake levels would be higher during spring months, but should stay within the existing lake shoreline and not inundate lands above the lake's high water line. No relocations would be necessary, but flood easements might be required. Water would be released through the control structure into Palmer Creek in the summer for irrigation or other purposes.

4.1.5.2. Water Source and Quantity

Palmer Lake is located at the terminus of Sinlahekin Creek, which has a drainage area of approximately 291 square miles and a watershed mean annual precipitation of 22 inches. Using estimates from a USGS gage located near Loomis, it is estimated that 189,000 acre-feet of flow enter the lake during an average year. Water supply for a storage project may not have to come from Sinlahekin Creek inflows, however, but may instead be diverted from the Similkameen River, which has an average annual flow of 1.7 million acre-feet as measured at Nighthawk. Water levels in the Similkameen River are high enough during spring floods to allow gravity diversion from the Similkameen into Palmer Lake through the control structure.

The normal water surface elevation of Palmer Lake is assumed to be 1144 feet. An upgraded reservoir would have approximately 10,500 acre-feet of potential storage between the normal water surface elevation and a high water level of 1149 ft (CH2M Hill, 1990). The Similkameen River and Sinlahekin Creek have annual spring flows that would be sufficient to supply this amount of water to Palmer Lake every year.

4.1.5.3. Potential Constraints

Impacts to Palmer Lake are anticipated to be minor and may include prolonged inundation of grazing areas located at the north end of the lake and small changes in the flood profile (CH2M Hill, 1990). Septic systems for some shoreline residences may need to be relocated so that they will not be inundated with groundwater. No mitigation is expected to be required. A water right for this project has previously been obtained by Oroville Tonasket Irrigation District (OTID), although the project was never built. Additional feasibility analysis in the form of hydrologic studies and geotechnical investigations are necessary due to changes in conditions since 1990.

The Okanogan PUD is performing an ongoing study for potential water storage along the Similkameen River at Shanker's Bend, located downstream of Palmer Lake. Development of storage on the Similkameen would preclude the ability to develop storage on Palmer Lake. This alternative should be coordinated with any developments for the storage project on the Similkameen River.

4.1.6. Similkameen River

The Okanogan PUD is performing an ongoing study for potential water storage along the Similkameen River, principally at Shanker's Bend. Other sites along the Similkameen River in both the United States and Canada have been studied in the past, although dams at Shanker's Bend appear to offer the best opportunity for water storage. Three heights of dams are being considered at this location: a low, a medium, and a high option.

The highest of the three dam alternatives at the Shanker's Bend Site is designed to maximize water storage and provide up to 1.3 million acre-feet of active storage. The reservoir would have a maximum water surface elevation of 1289 feet and create a backwater pool that extends well into Canada. The medium dam alternative is designed with a maximum operating reservoir water surface elevation to keep the reservoir pool within the United States. The medium dam reservoir would provide 138,000 acre-feet of active storage. The low dam alternative is designed to maintain the water level in Palmer Lake below the current flood level and avoid flooding the orchards and housing around Palmer Lake during normal operation. The low dam reservoir would provide 20,000 acre-feet active storage. A potential constraint is that any dam developed along the Similkameen River at this location would impact the ability to develop other storage projects on the Similkameen River or at Palmer Lake.

Large projects such as those being considered at Shankers Bend would provide water supply and environmental benefits within WRIA 49. This provides an opportunity for the planning unit to become a participant in these larger projects to secure water resource benefits for WRIA 49.

4.1.7. Other Surface Storage Sites

In addition to the surface storage projects discussed in the previous section, other sites were identified but were not considered highly prospective as storage opportunities. In most cases, these sites were considered infeasible due to an inordinate size of structure in proportion to available storage, a lack of sufficient water supply, impacts to irrigable or environmentally sensitive land, difficult access or construction characteristics, or a combination of these. Additional data collection and evaluation may yet reveal a feasible project, but the opinion of feasibility potential for these projects is low at this level of analysis. These projects were evaluated and the results of this analysis are described below.

4.1.7.1. Swamp Creek – SC1, SC2

Surface storage may be possible at sites along Swamp Creek. This creek drains into the Columbia River and an inter-basin transfer would be necessary to benefit uses in the Okanogan basin. If a storage project could be developed that would deliver water supply to Swamp Creek customers who are using Okanogan Basin water, it is possible that an exchange agreement could be developed. Swamp Creek water users would receive water from a new storage project, thereby making additional water available in the Okanogan Basin at the point of turnout. It appears that most water rights holders in the Swamp Creek basin pump water from the Columbia River instead of the Okanogan River, however, so the probability of identifying such an exchange agreement is low.

4.1.7.2. Omak Creek – OM2

A small storage site may exist along the Omak Creek within the Colville Reservation. A 40-ft high earth-fill dam could be constructed at the identified location that would provide 300-400 acre-feet of potential storage capacity. The creek at this location is entrenched deep in a narrow channel that does not provide much storage given the size of the structure.

4.1.7.3. Salmon Creek – SA2, Others

A rock outcrop located just below the confluence of the South Fork and West Fork of Salmon Creek represents a suitable foundation for a dam. This site is identified as SA2 and, at this location, an arch or concrete dam up to 80-ft high could be constructed, which would have a crest length of 515 feet and a maximum potential storage capacity of 1,700 acre-feet. The site has several issues that would likely preclude its development. First, there are many houses located in the inundated area, which would have to be purchased. Second, the creek drains into Conconully Dam, which likely owns most or all of the water rights for this creek. Finally, a road that runs adjacent to the creek on a steep hillside would have to be relocated, which would be difficult and expensive.

Other surface water storage opportunities have been identified in the recent past as part of a study on Salmon Creek (Pratt, 1999) to assess the ability to provide in-stream flows for fish while preserving irrigation deliveries. The study identified several storage opportunities, and two feasible surface storage projects were identified. The first was a pump storage project whereby water would be pumped from Salmon Creek into Brown Lake, which would be raised by the addition of saddle dams on each side of the lake. The total capacity of the reservoir was estimated as 10,000 acre-feet and the total cost (in 1999 dollars) as $7.3M. This project was eliminated due to prohibitively high costs per acre-foot storage. The second project was to raise Conconully Lake Dam by 2 ft so that additional winter runoff could be captured. The total estimated cost for the project (in 1999 dollars) was $2.1M.   This project was eliminated due to the creeks inability to provide sufficient water.

4.1.7.4. Bonaparte Creek – BP2, BP5

In addition to those discussed earlier (BP4, BP6, and BP7), two other sites were considered along Bonaparte Creek but are deemed less promising. BP2 is a site located just below the confluence of Bannon Creek and Bonaparte Creek. At this location, the creek opens into a wide floodplain that would represent an opportunity for storage. A long earth-fill dam could be constructed up to 50 feet high, with a crest length of 1300 feet, a reservoir of 200 acres, and a maximum storage capacity of 4,100 acre-feet. The major constraint is that the reservoir would inundate a large amount of irrigable land. Also, while a storage project could be built up to 50-feet high, it is unlikely that there is sufficient water passing that location to support a reservoir of that height. If optimization of the structure size were performed, the dam height would likely be significantly lower. A smaller structure at this location would likely be too costly for the water supply benefit it could produce.

The other location considered along Bonaparte Creek was BP5, which is located along the main stem, upstream of the confluence with Little Bonaparte Creek. At this location, rock abutments are present on both banks that would allow for an earth-fill structure up to 80-feet high, although it is unlikely that there is sufficient water passing the site to warrant a structure of that height. If a dam were built 80-ft high, it would have a crest length of approximately 750 feet and a storage capacity of approximately 1000 acre-feet. Significant drawbacks are that it would inundate all irrigable lands and would present road location issues. Also, although the abutments are rock, some of the rock appears not to be suitable for a dam. Similar to BP2, a smaller structure at this location would likely be the result of an optimization analysis, but it would probably be too large and costly for the water supply benefit it could produce.

4.1.7.5. Sinlahekin Creek – SN2, SN3

Storage projects along the Sinlahekin Creek are appealing because of high runoff volumes per drainage area and less housing and agricultural development than on the east side of the Okanogan watershed. In addition to site SN1 located at the outlet of Palmer Lake, two additional sites were considered located directly on the Sinlahekin Creek, named SN2 and SN3.

SN2 is located south of Loomis, just upstream of the confluence of Cecile Creek. At this location, it was estimated that a 100-ft high earth-fill or concrete dam could be constructed that would have a crest length of 500 feet and a potential storage capacity of 5,600 acre-feet. The primary constraining issue with a dam at this location is that it would be in the Sinlahekin Wildlife Area and would flood many acres of wetlands and other sensitive habitats.

SN3 is located in the steep canyon along the Sinlahekin upstream of Blue Lake. At this site, a very high dam would be required in order to provide any significant storage, and steep roads would make access extremely difficult. If access issues could be resolved, a 150-200 ft high arch or concrete dam could be constructed, which would provide only 800-1000 acre-feet of storage capacity. This site is not recommended for further development because less expensive alternatives are available (SN1, SN2) further downstream. Even with the addition of hydropower, the feasibility of this project is doubtful.

4.1.7.6. Toats Coulee Creek – TC1, TC2

Toats Coulee Creek is a rocky, mountainous creek that drains into the Sinlahekin Creek near Loomis. Runoff in the watershed is greatly affected by snowmelt, and spring flows are extremely high compared to the east side of the Okanogan Valley. Two storage locations were considered along Toats Coulee Creek. The first is just upstream of the existing diversion structure that diverts water for delivery to Spectacle Lake, and the second is further upstream along the North Fork. Both of these sites would require high concrete or arch dams in order to achieve significant storage capacities. Construction would be difficult due to limited access and staging areas. At site TC1, it was suggested at a meeting of the Okanogan Watershed Planning Unit that a geologic fault may run nearby the site, which would be a significant deterrence a dam at this site. For both locations, the amount of water storage would be very low, as compared to the cost of the dam.

4.1.7.7. Remaining Sites

Figure 4-1 shows a number of remaining sites other than those discussed in this section. In the process of considering surface storage opportunities, all major tributaries were considered and locations that appeared to provide the potential based on topography were identified. The remaining sites have since been eliminated from further analysis by one or a combination of factors, such as lack of available water supply or storage, preclusive site constraints such as inundation of irrigable lands or lack of a suitable foundation, lack of access, or lack of suitable construction materials.

Sites from previous surface storage studies (see Section 2.0) were also considered as part of this analysis. Those storage sites not discussed in this section were considered infeasible due to prohibitive costs, environmental constraints, lack of available water, or previous analyses that have already proven these sites to be infeasible for other reasons.

4.2. Groundwater Storage Sites

4.2.1. Watershed Description and Subbasin Characteristics

The Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service, has prepared a survey report of shallow soil conditions in the Okanogan Basin (NRCS, 1979). The NRCS survey indicates that soils in the subbasins, as well as the northern part of the valley floor, consists mostly of loams, sandy silt loams, and silt loams. A loam is essentially a mixture of soil particles of different grain sizes, and the modifiers (sandy, silt, etc.) indicate the dominant component or components. Some coarser soils are located adjacent to the Okanogan River in places. Further south in the Okanogan Valley, soils consist of loams, sandy loams, gravelly loams, and silt loams. Few soils were identified that are composed of sand and gravel and are free or mostly free of silt; where fine-grained particles such as silt or clay are present in significant proportions, soil permeability tends to be low regardless of the presence of sand or gravel.

Groundwater is the primary water source for most water uses in WRIA 49, except in a few areas where water from the Okanogan River and its tributaries is used for irrigation. Groundwater (including springs) is the sole drinking water source, and as a result, there are many wells in the basin. A review of the Washington Department of Ecology’s on-line drillers report/well log database identified over 1,000 well logs, mostly within the Okanogan River Valley, but also in the major tributaries (WDOE, 1999). Analysis of well logs was performed with intent to identify general areas within WRIA 49 where hydraulic pathways exist between the surface and water table. A more detailed review of hydrogeology and soils at specific locations will be necessary as part of further investigations of individual projects. Wells in the data set are 365 feet deep or less and most are less than 150 feet deep. Groundwater quality for samples collected from these wells is generally very good, although local pockets of low-level nitrate contamination have been observed.

A description of geology and hydrogeology by subbasin was performed as part of the WRIA 49 Level 1 Assessment (ENTRIX, 2006). On the west side of the Okanogan River, in the Sinlahekin Creek subbasin, groundwater was noted to be generally limited to glacial and alluvial deposits located in abandoned or partially abandoned river valleys, resulting from historic routing of the Similkameen River through this area. Deposits in these areas are several hundred feet thick with moderate to high yield aquifers. Along the current route of the Similkameen River, however, few glacial or alluvial deposits results in little groundwater potential. Further south, mountainous terrain in the tributary headwaters provides limited opportunities for groundwater storage except in areas along the Okanogan River floodplain, where glacial and alluvial deposits have been documented up to 100 feet thick. In isolated areas, such as the Salmon Creek Valley and Chiliwist Creek Valley, unconsolidated sediments have been noted to be up to 300 feet thick, which may provide some potential for groundwater storage. In general, however, little unconsolidated sediments provide few opportunities for storage.

East of the Okanogan River, glacial, alluvial, and lucustrine deposits are present in widely varying depths, particularly along the Okanogan River floodplain. Bedrock is exposed in many of the areas above the floodplain, however, and significant groundwater storage has been noted to predominantly be limited to areas near the Okanogan River or in lower reaches of the major tributaries such as Antoine Creek or Bonaparte Creek.

4.2.2. Potential Managed Aquifer Storage Sites

Possible groundwater sites initially identified in this study are shown on Figure 4-6. Areas evaluated in this study were considered to have a reasonable potential for managed aquifer recharge and storage if the following criteria were identified:

1. Surface soils are relatively coarse and conducive to infiltration.
2. Sediments are sufficiently thick (relative to both depth to bedrock and elevation above the primary stream drainage channel) to provide potentially substantial storage volume.
3. Lateral extent of sediments meeting requirements 1 and 2 and are of a sufficient extent from the stream to prevent rapid discharge to the draining creek or river or to lower terrain. This enables some control over the duration of storage.
4. A source of surface water is available within a reasonable distance (assumed to be two miles or less) and at sufficient quantities during periods of high flow for partial diversion to aquifer storage.

Two areas were identified with some potential for limited groundwater storage at volumes that would warrant further evaluation. These areas include the upper part of the Antoine Creek Subbasin (Site GW-5) and the lower reach of the Salmon Creek Subbasin (Site GW-13). These are discussed below.

The availability of water rights for diversion from surface water to groundwater storage has not been determined for any of the sites discussed below. Also, the quantity or seasonal availability of water that may be available above required minimum in-stream flows has not been determined.

4.2.3. Upper Antoine Creek Subbasin – GW5

4.2.3.1. Location and Site Characteristics

The upper Antoine Creek Subbasin consists of a relatively wide valley with exposed bedrock located on the surrounding hills, terraced alluvial deposits in the valley floor, and a broad floodplain with a moderately incised stream channel. Surface sediments include fine sand, fine gravelly sand, and silty sand. Well logs indicate that the relative proportion of fine sand and silt may increase from the surface to the water table, which is at or above the elevation of Antoine Creek. This area may have some potential for recharge because surface soils tend to be relatively high in sand content. Water would be directed to infiltration ponds, which would be sized depending on aquifer infiltration and storage potential. Infiltrated water would move toward Antoine Creek to either recharge the creek or for withdrawal by wells.

4.2.3.2. Water Source and Quantity

The source for managed aquifer recharge would be Antoine Creek in the upper Antoine Creek Valley. The most practical means of conveyance from the creek to recharge basins would be by diverting the creek into a gravity pipeline at a higher elevation in the subbasin. Locations for a diversion and gravity pipeline were not identified for this analysis.

Assuming that the least-permeable subsurface soil above the water table is a silt loam, a maximum infiltration rate of 0.4 inches/hour would be possible (Anderson 1998). A more reasonable average rate of infiltration would be 0.2 inches/hour. Land in the upper subbasin is primarily used for agriculture in the lower elevations and forest/rangeland in upper elevations. Low-lying land would probably provide less storage volume than higher land because the water table there is expected to be shallow. Assuming that 100 acres of higher land could be found for recharge and that 2/3 of this land could be available for recharge at any given time over a 3-month period, a recharge volume of approximately 2,400 acre-ft/yr might be possible. Some discharge of recharged water to Antoine Creek probably would occur, but at this time not enough information is available to predict the amount of water or timing of return flows.

4.2.3.3. Potential Constraints

Well logs suggest that there is an apparent fining of soils with depth, indicating that permeability of subsurface soils may be lower than surface soils in some areas. The volume of aquifer storage has not been quantified but may be limited because the sediment terraces along the valley margins are narrow, and the valley floor groundwater is only 25-75 feet deep. This could be partially mitigated by placing recharge basins near the upper margins of the valley and near the edges of the valley, thereby increasing the distance from the recharge basins to Antoine Creek and providing greater travel time and, therefore, more storage.

4.2.4. Lower Salmon Creek Subbasin – GW13

4.2.4.1. Location and Site Characteristics

The lower Salmon Creek Subbasin is a terraced area on the west side of the Okanogan Valley from the mouth of Salmon Creek Canyon to the western edge of the Okanogan Valley floodplain. Soils are relatively coarse with abundant sand and some gravel, primarily in a sandy matrix. Some silt is present in most soil outcrops as suggested by limited well logs. Recharge basins would probably be located on the top of the terraced area as far from the valley floor as practical. This area has the advantage of a coarse terraced area several hundred feet thick and several hundred feet wide, providing a reasonable storage area with some residence time before discharge to either Salmon Creek or to the valley floor via seepage, assuming that mounding of recharged water would tend to flatten over time.

A previous study by Dames and Moore (1999) identified this area for a potential managed aquifer recharge project. The preliminary study suggested that this location would warrant further evaluation but recognized that the limited data are insufficient to adequately determine the suitability of this site for recharge.

4.2.4.2. Water Source and Quantity

Recharge water would be obtained from Salmon Creek. It may be possible to intercept flow from Salmon Creek further upstream, east of the mouth of the canyon, enabling gravity flow in a pipeline to the points of recharge. If a surface storage reservoir is developed nearby, such as the reservoir site SA1, discussed earlier, a joint-storage opportunity may be available that would help increase yield of the groundwater project. If these options are not possible, water would need to be pumped from Salmon Creek to recharge basins on the terraces.

Assuming that the most restrictive soil type that would be encountered in the subsurface above the aquifer would consist of a fine sandy loam, the maximum infiltration rate in this type of soil would be 0.5 inches/hour or less (Anderson 1998). However, the maximum infiltration rate is rarely sustainable due to various factors such as trapped air, clogging, biological growth, settling, and other considerations. For an idea of the available capacity, the following was assumed: an average infiltration rate of 0.25 inches/hour; a maximum of 2/3 of a 100-acre infiltration basin; a recharge period of three months per year; and an "unlimited" availability of surface water for recharge. With these assumptions, a recharge volume of approximately 3,000 acre-ft/yr could be achieved, or about 1,000 acre-ft/month. This would require a constant flow of 16.8 cfs. Thus, by this estimate, approximately 3,000 acre-ft/yr could be put into groundwater storage under a managed aquifer recharge program. Some discharge of aquifer recharge water to Salmon Creek probably would occur, but not enough information is available at this time to predict the amount.

4.2.4.3. Potential Constraints

This scenario probably would result in partial discharge to Salmon Creek, and losses of recharged water to the creek or the valley could be substantial unless a well-spaced line of recovery wells were placed along the valley-ward edge of the terraces. Limited well logs suggest that the proportion of silt is greater in some subsurface soils, which may reduce long-term recharge rates. If water must be pumped from Salmon Creek rather than diverted by gravity, capital costs would increase and operational costs would be substantially higher due to energy costs.

4.2.5. Other Groundwater Storage Sites

4.2.5.1. Okanogan River between Tonasket and Omak – GW8

Sandy gravelly soils are common in hummocky terrain along the west side of the Okanogan River Valley between the cities of Tonasket and Omak. Several small ponds are present in depressions in this area, particularly south of Pine Creek Road. Recharge by means of infiltration basins may be possible in this area, and some storage may be possible. Diversion from Fish Lake may be feasible. However, control of stored recharge in this area would be difficult because recharged water would seep into hummocky depressions or the Okanogan Valley floodplain. This site does not appear to be favorable for managed aquifer storage.

4.2.5.2. Okanogan River South and Southwest of Okanogan – GW14.

Terraces along the southwest edge of the Okanogan River Valley, west of the towns of Mallot and Wakefield, contain gravelly sand deposits and may be suitable for recharge. The narrow width of the terraces indicates that only limited storage is available. It it is doubtful that a surface water source could be identified for diversion to this area by means of gravity flow.

4.2.5.3. Side-Channel Storage along the Upper Okanogan River.

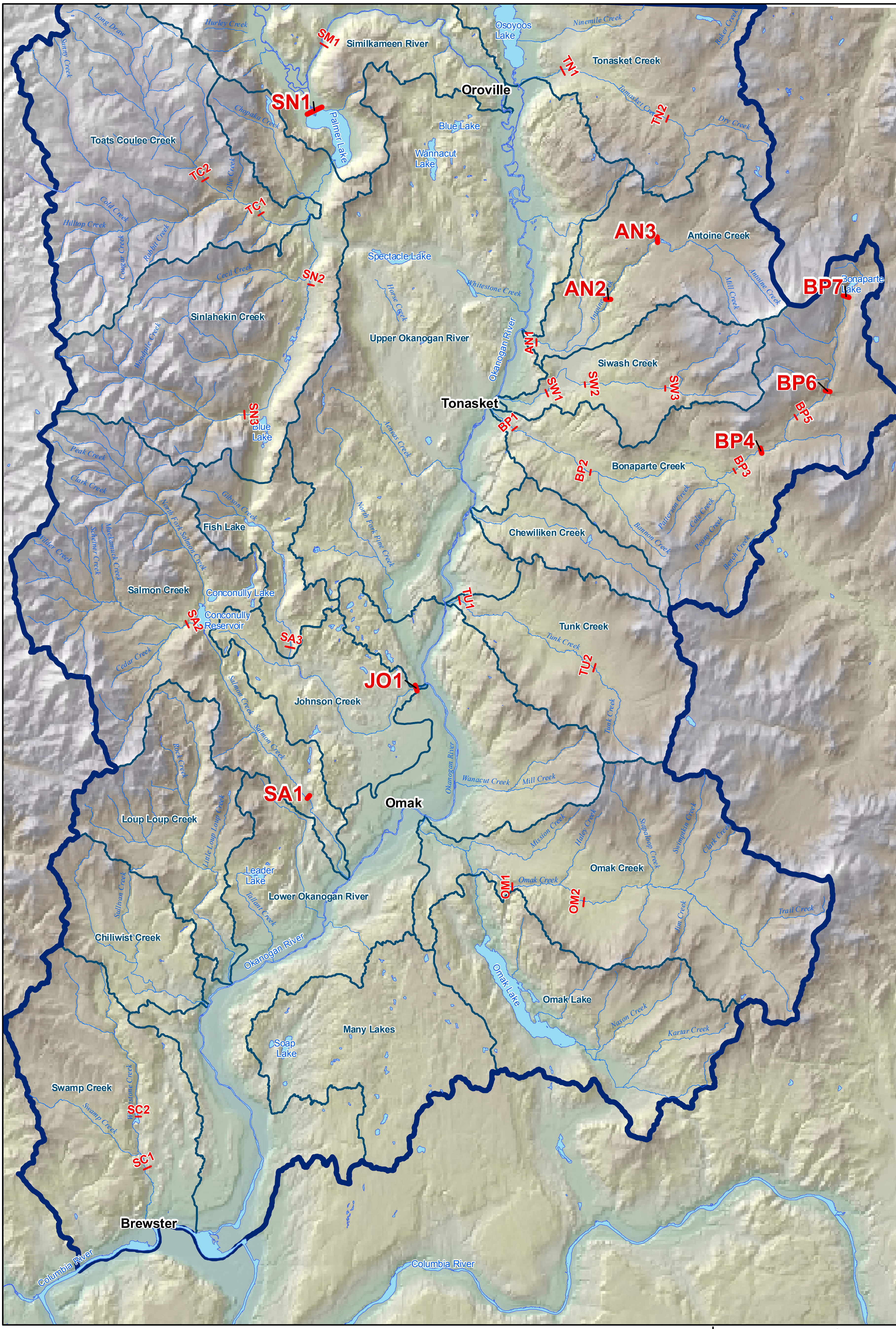
Natural oxbows or other side-channel storage in the form of constructed trenches or shallow wells along the Okanogan River floodplain may provide a local or even a limited regional source of water. Additional benefits may include natural bank filtration that may result in lower turbidity than river water. Analysis of soil maps and field observations, however, suggest that the upper reaches of the Okanogan River are gaining flow from ground water and that water levels between the Okanogan main stem and side-channel storage sites are hydraulically continuous. Development of side-channel storage would decrease recharge to the Okanogan River and significant development could impact surface flows in the Okanogan River.

4.2.5.4. Sinlahekin Creek at Blue Lake.

A dam was constructed at Blue Lake in 1923 and then abandoned as a surface storage project in the 1930's because groundwater infiltration out of the reservoir was excessively high. Currently, Blue Lake is still used to store some high spring flows from Sinlahekin Creek, which then infiltrates from Blue Lake back to Sinlahekin Creek over the course of the summer. Enhancing the existing facilities in order to allow more water to be diverted into the Lake may represent an opportunity as a combined surface/groundwater project. While this may be feasible, this project is not considered highly prospective because it does not appear to represent a reliable way to store and recover either surface or ground water supplies.

4.2.5.5. Remaining Sites

Initially, 14 sites were evaluated for potential groundwater storage opportunities. See Figure 4-6. Those sites not mentioned above were eliminated based on one or a combination of factors, including limited potential groundwater storage volume, presence of silty, gravelly, or sandy soils or soils with fines, high potential for seepage loss back to the river, or developmental or environmental constraints. See Appendix A for field notes evaluating each identified site.



Legend

- Rivers & Streams
- Lakes
- WRIA 49 Basin
- WRIA 49 Subbasins
- Further Analysis Sites - Text Type = **AN2**
- Other Sites - Text Type = **SC1**

WRIA 49 Water Storage Assessment

0 1 2 4 6 8 Miles

WRIA 49 Water Storage Assessment

1:300,000 Scale

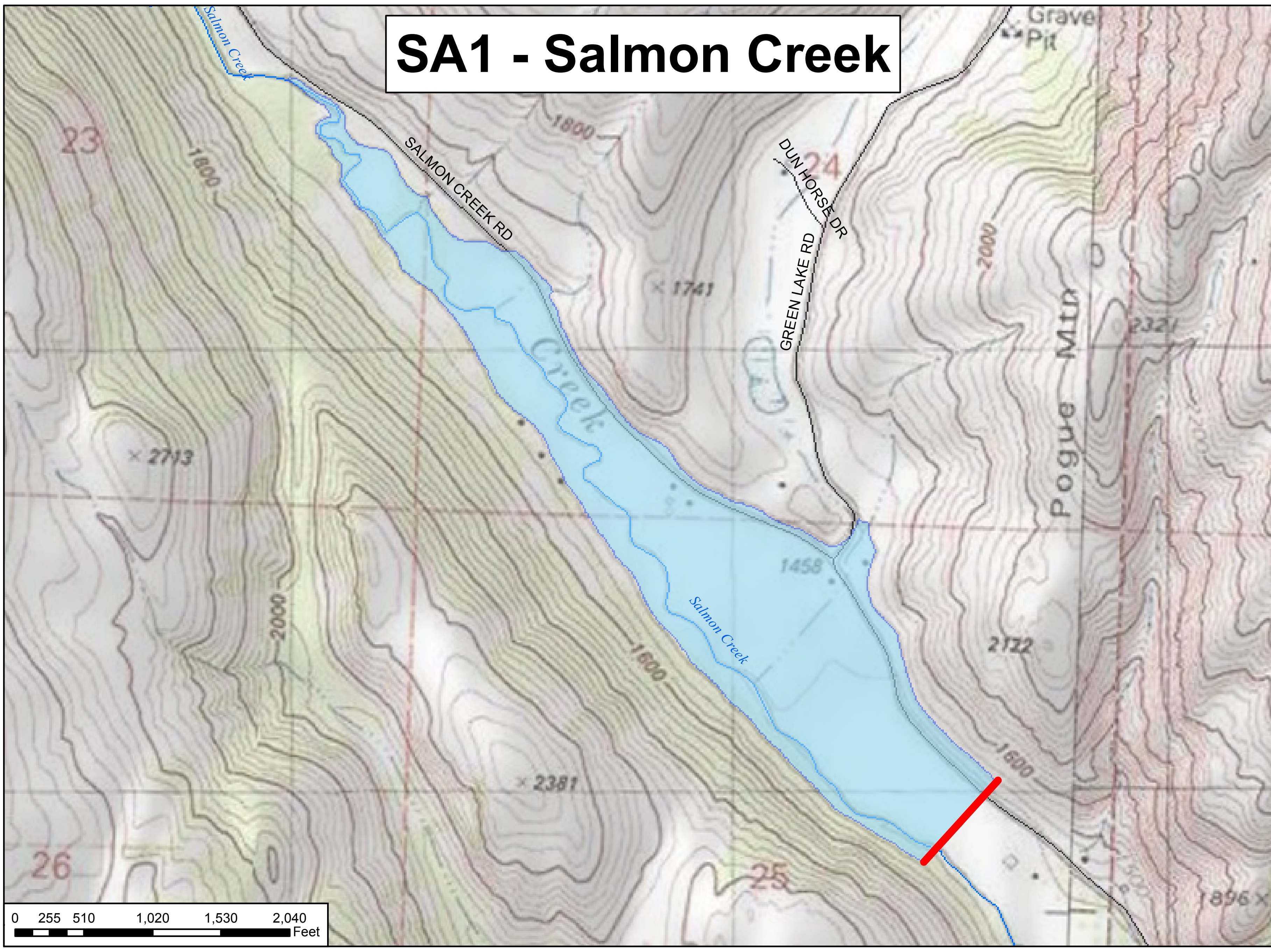
Spatial Reference: UTM Zone 11N, NAD-83

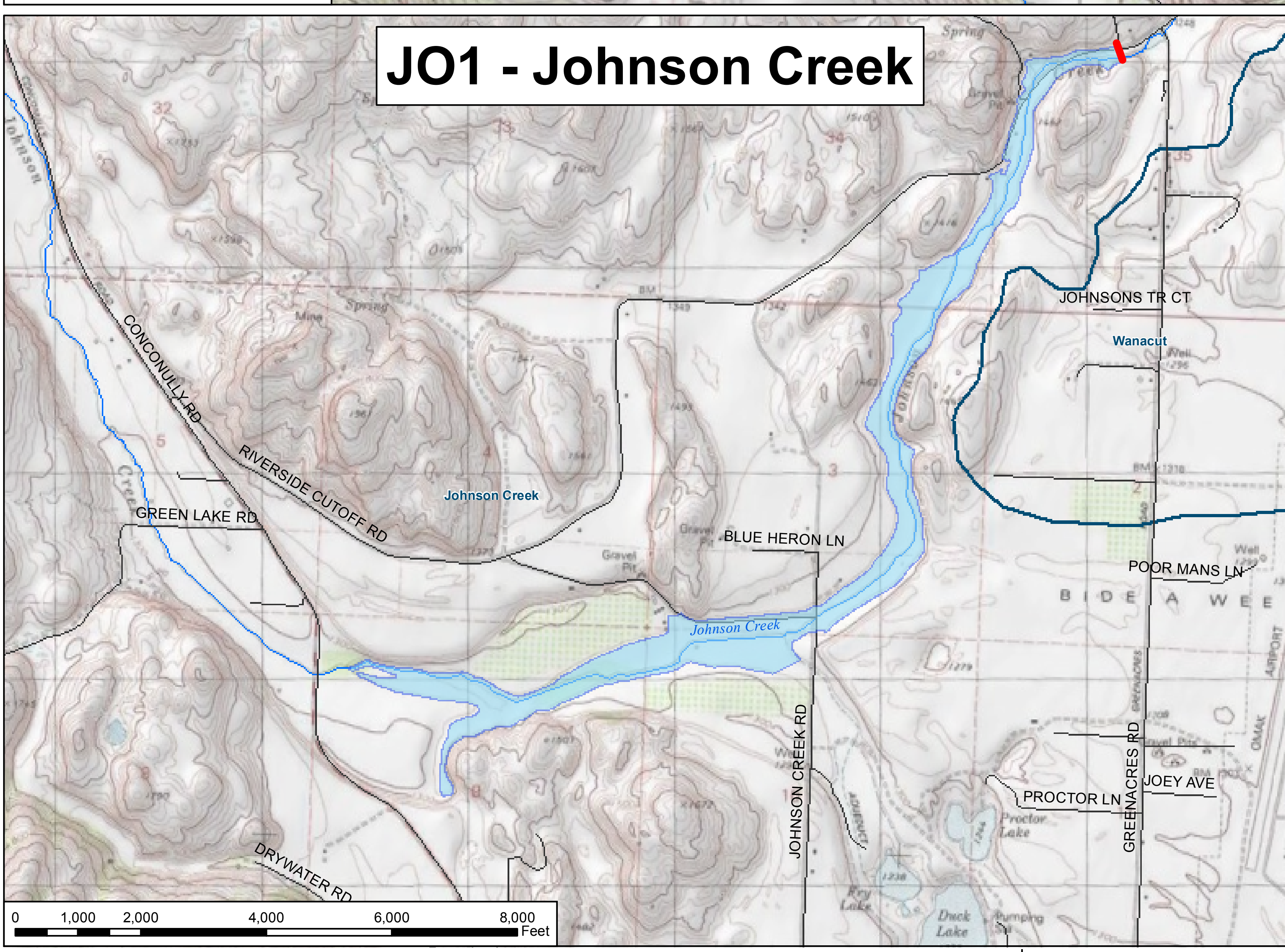
N

Figure 4-1

MWH

Locations of Surface Storage Sites in the WRIA 49 Watershed





Legend

- Proposed Dam Site
- Proposed Reservoir
- Rivers & Streams
- Okanogan River Basin
- NGS USA Topographic Maps

WRIA 49 Water Storage Assessment

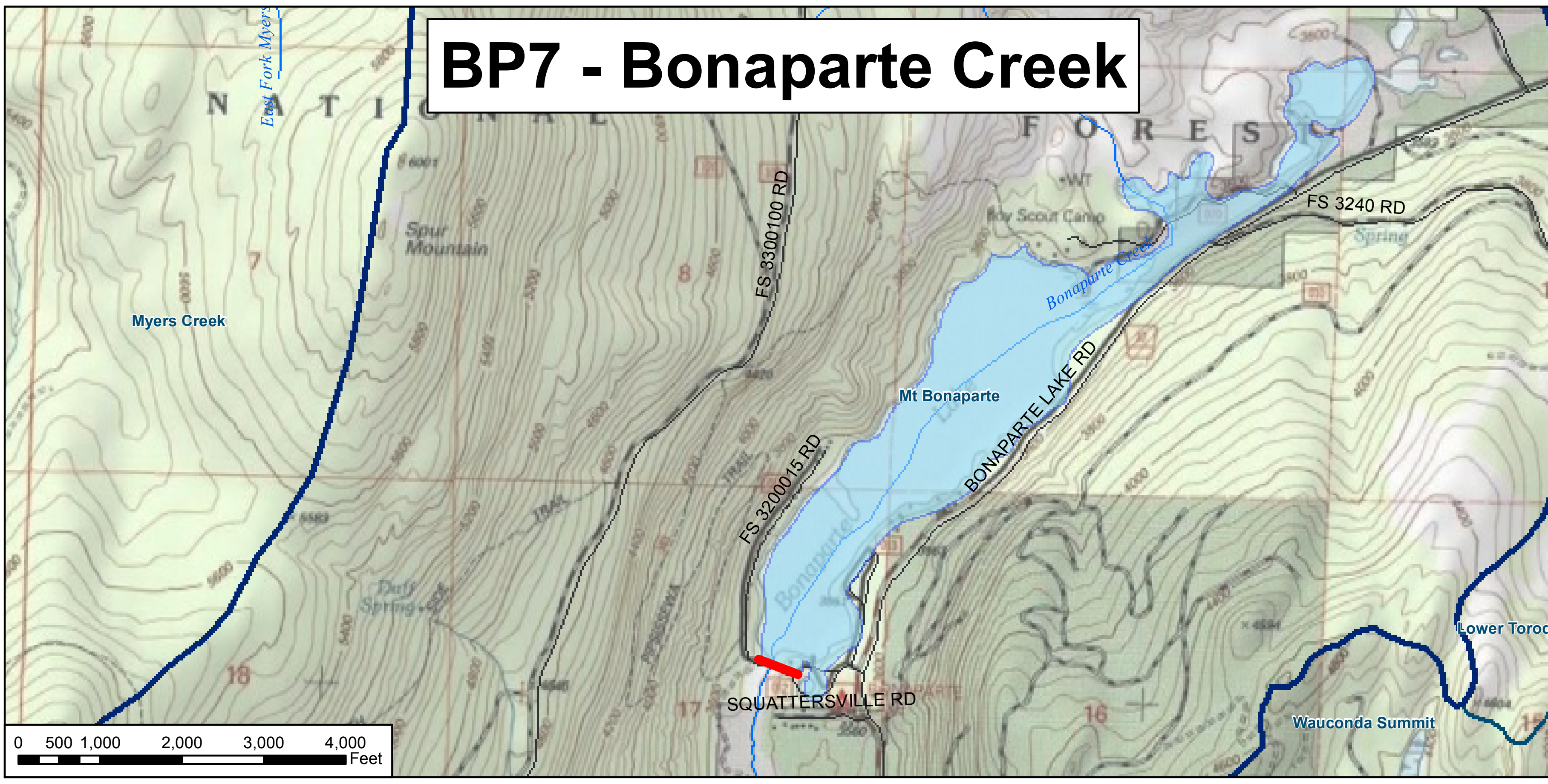
WRIA 49 Water Storage Assessment

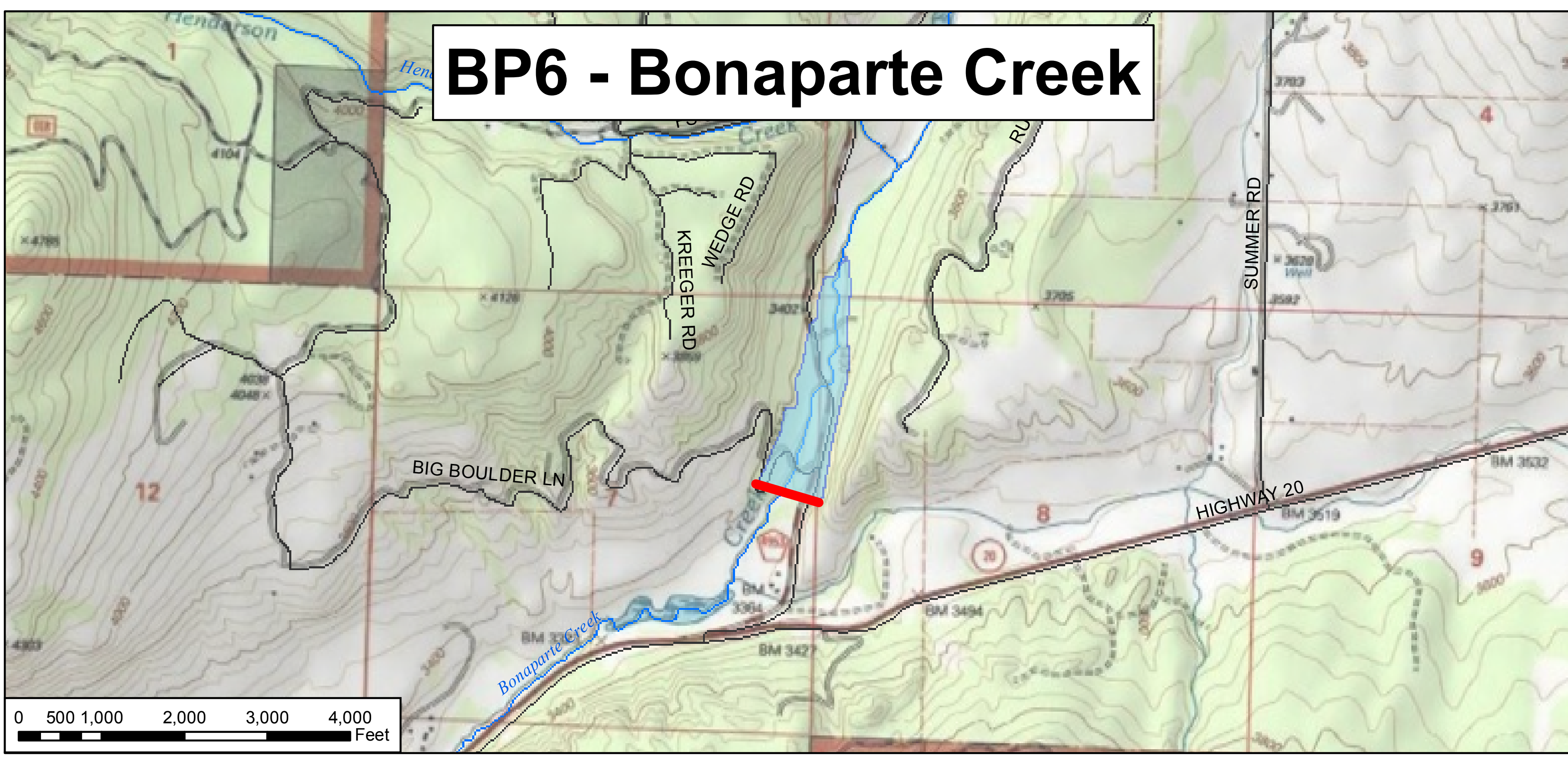
Spatial Reference: UTM Zone 11N, NAD-83

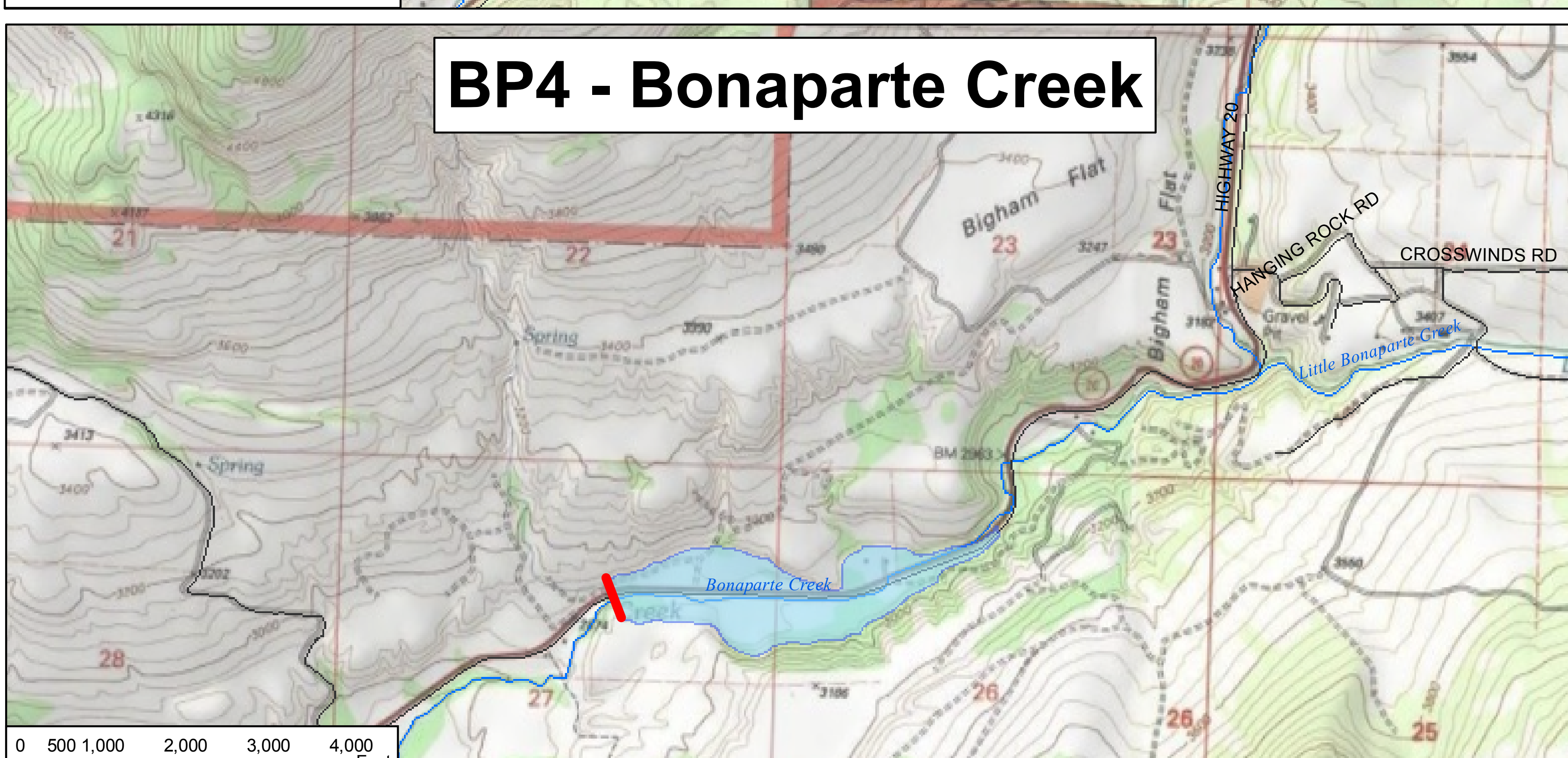
N

Figure 4-2 MWH

Storage Sites SA1 and JO1







Legend

- Proposed Dam Site
- Proposed Reservoir
- Rivers & Streams
- Okanogan River Basin
- Okanogan Subbasins
- NGS USA Topographic Maps

WRIA 49 Water Storage Assessment

WRIA 49 Water Storage Assessment

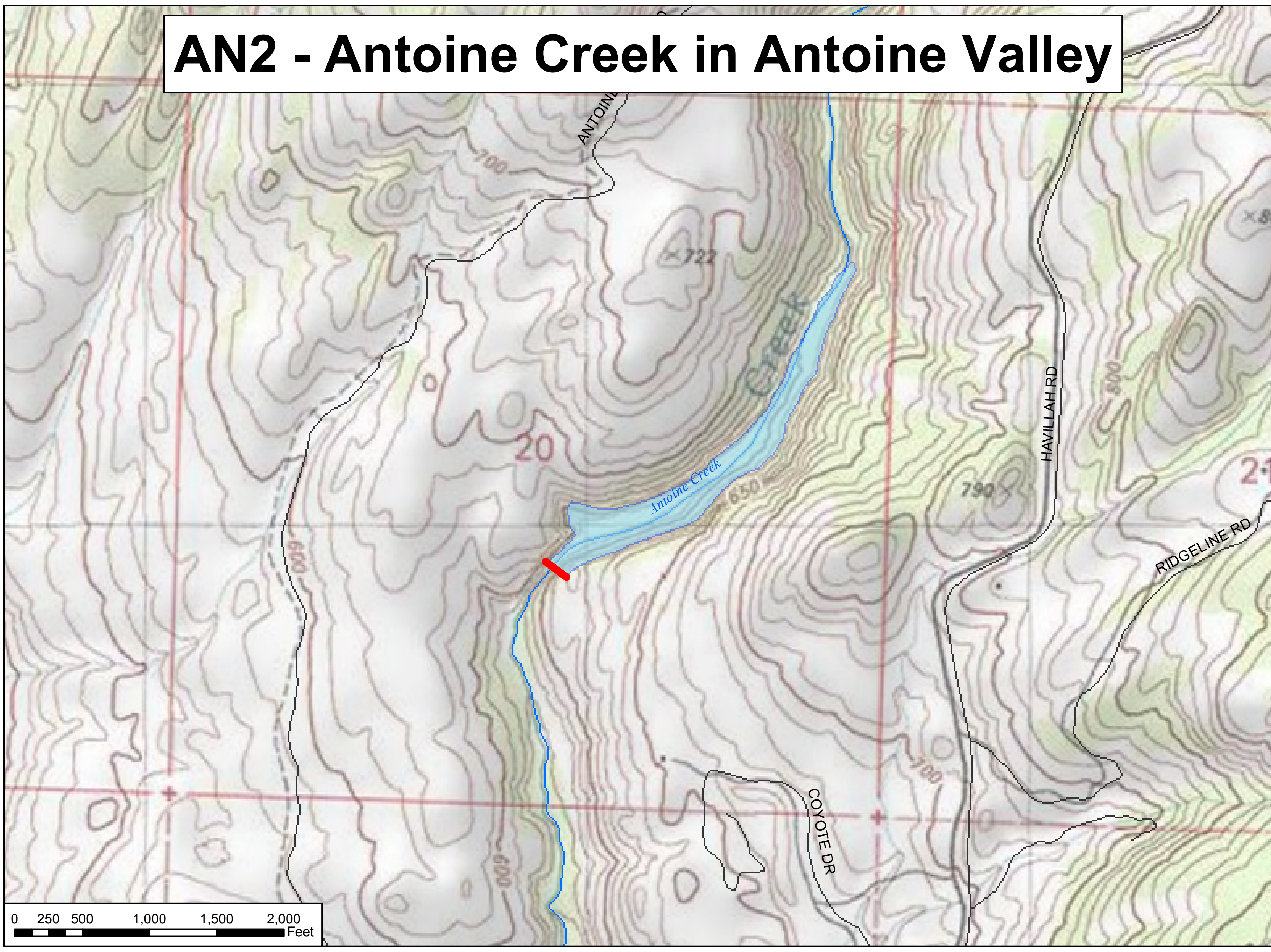
Spatial Reference: UTM Zone 11N, NAD-83

N

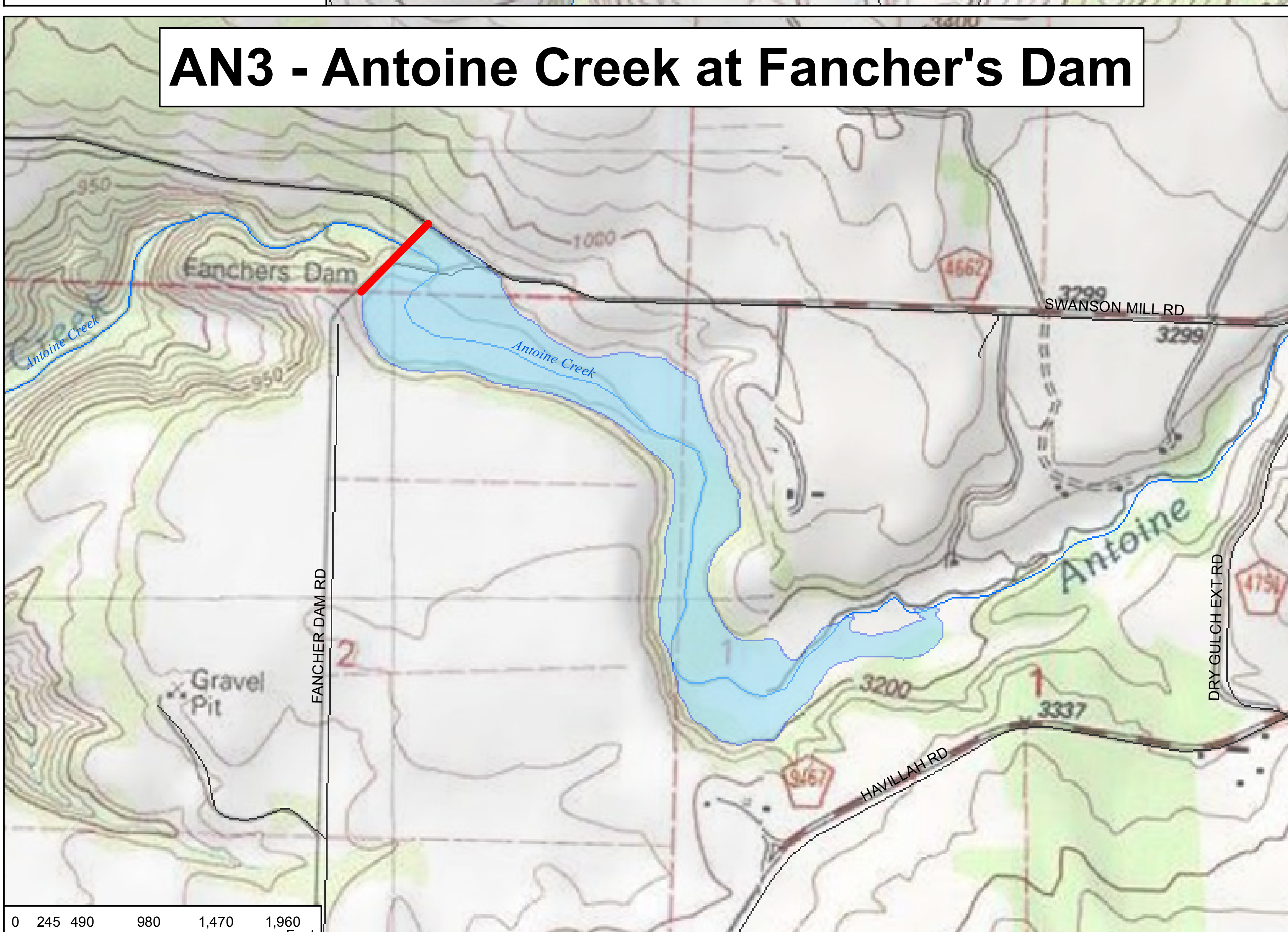
Figure 4-3 MWH

Storage Sites BP7, BP6 and BP4

AN2 - Antoine Creek in Antoine Valley



AN3 - Antoine Creek at Fancher's Dam



Legend

- Proposed Dam Site
- Proposed Reservoir
- Rivers & Streams
- Okanogan River Basin
- NGS USA Topographic Maps

WRIA 49 Water Storage Assessment

WRIA 49 Water Storage Assessment

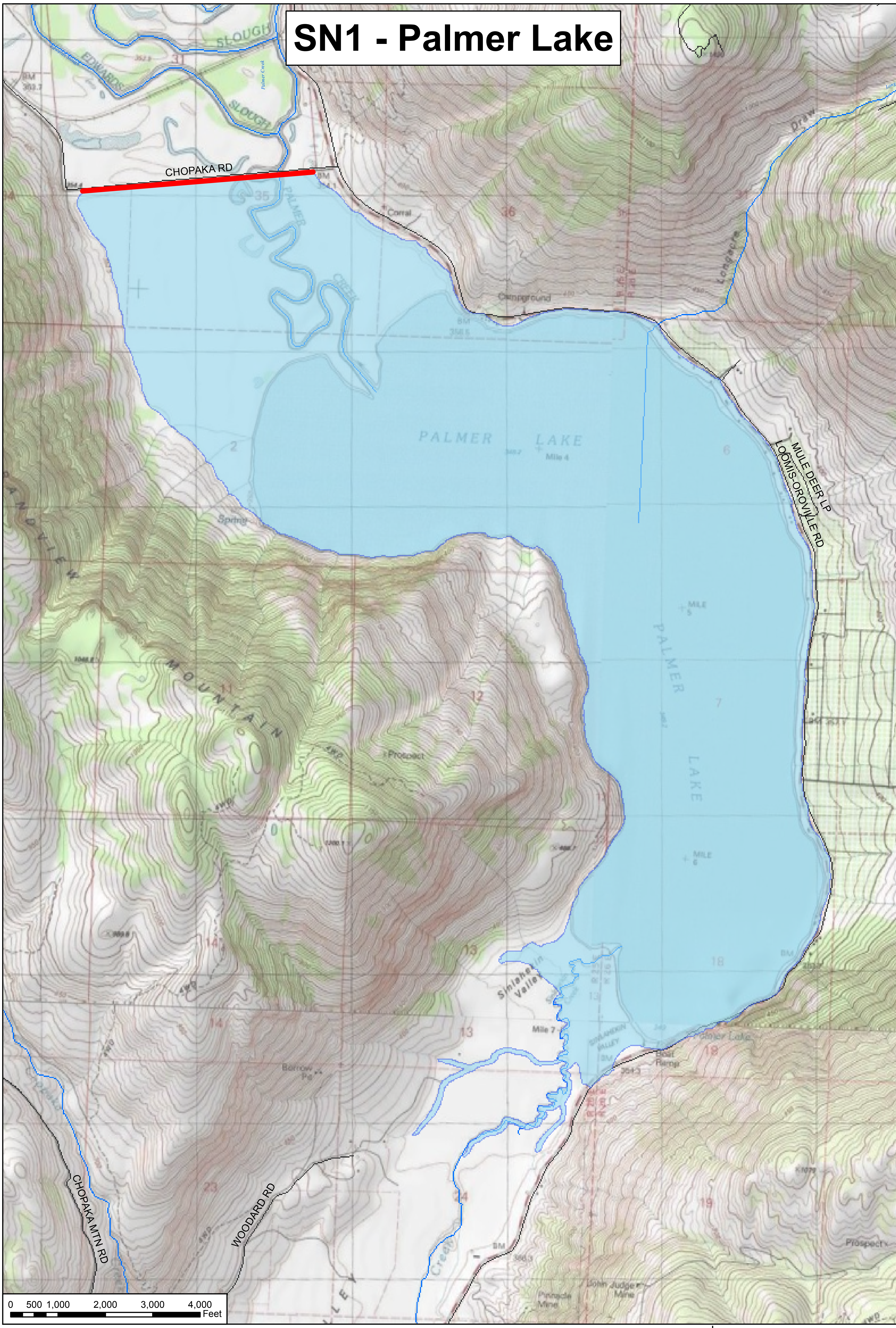
Spatial Reference: UTM Zone 11N, NAD-83

N

Figure 4-4

MWH

Storage Sites AN2 and AN3



Legend

- Proposed Dam Site
- Proposed Reservoir
- Rivers & Streams
- Okanogan River Basin
- NGS USA Topographic Maps

WRIA 49 Water Storage Assessment

WRIA 49 Water Storage Assessment

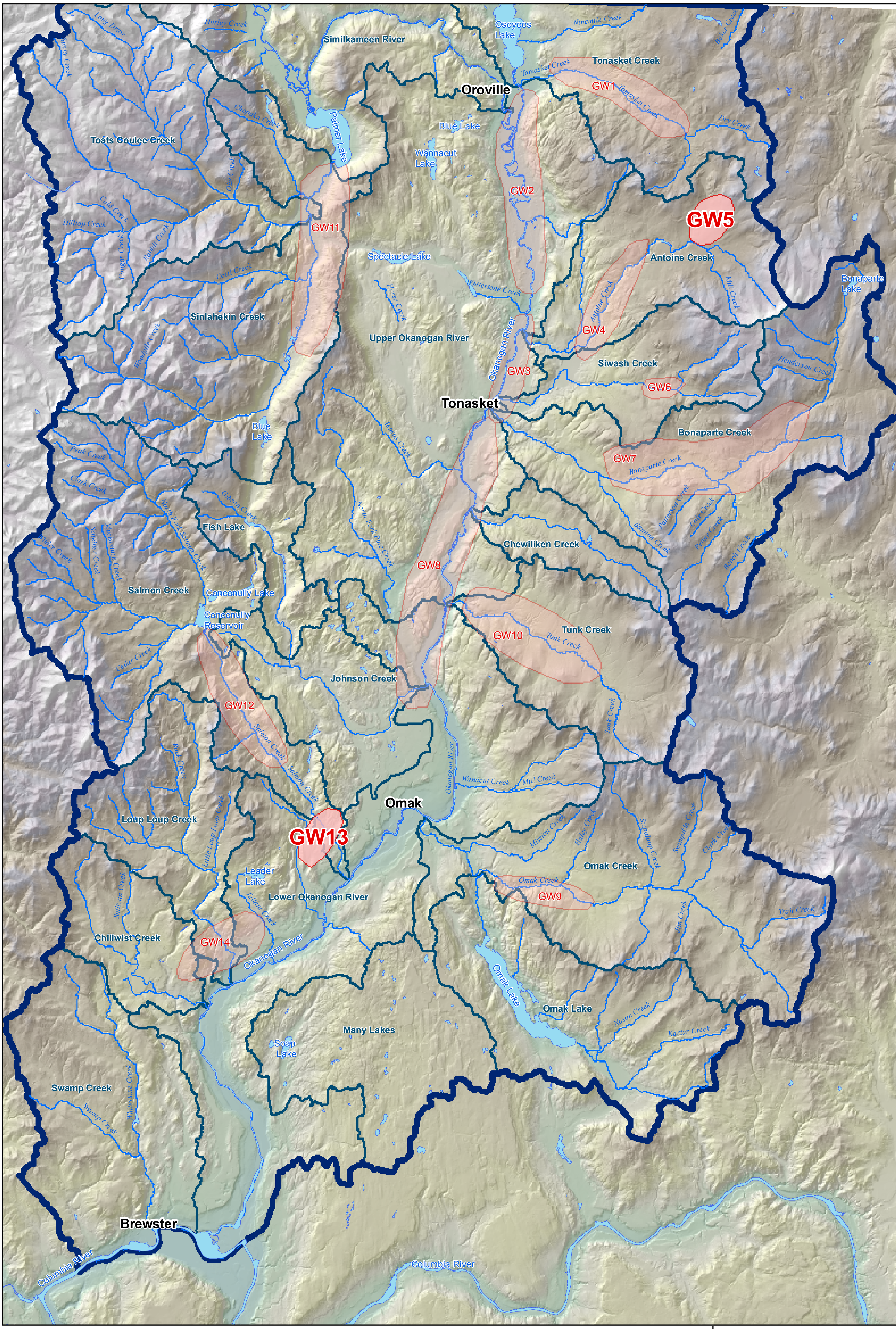
Spatial Reference: UTM Zone 11N, NAD-83

N

Figure 4-5

MWH

Storage Site SN1



Legend

- Rivers & Streams
- Lakes
- WRIA 49 Basin
- WRIA 49 Subbasins
- Further Analysis Groundwater Sites - Text Type = GW5
- Other Growndwater Sites - Text Type = GW9

WRIA 49 Water Storage Assessment

0 1 2 4 6 8 Miles

WRIA 49 Water Storage Assessment
1:300,000 Scale
Spatial Reference: UTM Zone 11N, NAD-83
N

Figure 4-6 MWH

Locations of Ground Water Storage Sites in the WRIA 49 Watershed

5.0 ESTIMATED EFFECTS ON WATER BALANCE

5.1. Water Balance from Level 1 Watershed Technical Assessment

As part of the WRIA 49 Level 1 Watershed Technical Assessment, a water balance for each major subbasin was computed. The water balance was estimated with the following equation:

$$P - ET \pm \Delta GS - MAF = 0$$

where *P* is the average annual precipitation, *ET* is the average annual evapotranspiration, *ΔGS* is the change in groundwater storage, and *MAF* is the mean annual flow (WRIA 49, 2006). Table 5-1 shows a summary of the subbasin water balances from the WRIA 49 Level 1 Report.

Data used to calculate the water balances for each subbasin were obtained from a variety of places. Precipitation data were obtained from recording stations operated by the National Climate Data Center (NCDC), the Western Region Climate Center (WRCC), and from Natural Resource Conservation Service (NRCS) precipitation contour maps. Stream flow data was compiled from over 60 streams and consisted of a combination of continuous and point data sources recorded by multiple entities, including the U.S. Geological Survey (USGS), the Bureau of Reclamation (Bureau), the Washington Department of Ecology (Ecology), the Colville Confederated Tribes, and the Okanogan Conservation District (OCD).

The change in groundwater storage would theoretically be the net interaction considering both recharge from groundwater and seepage from the stream to groundwater. Over the long-term, this interaction would produce an impact on the depth of the groundwater table. Since no long-term change in the depth of the water table had been observed, the change in groundwater storage (*ΔGS)* was estimated to be zero. Therefore, the equation for the water balance computations in the Phase I report became:

$$ET = P - MAF$$

Pan evaporation data were obtained from WRCC's station in Oroville, which recorded data from 1960 to 1970. Also, free-surface evaporation data from Conconully Reservoir was evaluated for the time period from 1956-1970 (Farnsworth and others, 1982). More recent pan or evapotranspiration data were not readily available. Since data for all other parameters in the water balance were known, evapotranspiration was estimated as the balance of the other parameters.

Table 5-1 WRIA 49 Computed Subbasin Water Balances (values in thousand acre-ft per year).

PRIMARY SUBBASIN	PRECIPITATION	ET	RECHARGE	MEAN ANNUAL FLOW	
				Groundwater Discharge	Rainfall and Snowmelt Runoff
Sinlahekin	436	359	22	22	56
Osoyoos	416	402	10	10	3
Omak	322	309	8	8	5
Salmon	402	367	20	20	15
Joseph	215	212	3	3	0.4
		Percentage of Precipitation			
		As ET	As Recharge (Gr)	As Groundwater Discharge (Gd)	As Runoff (R)
Sinlahekin		82%	5.0%	5.0%	12.8%
Osoyoos		97%	2.5%	2.5%	0.8%
Omak		96%	2.5%	2.5%	1.5%
Salmon		91%	5.0%	5.0%	3.8%
Joseph		98%	1.5%	1.5%	0.2%

Water rights on almost every major tributary to the Okanogan River may already be over appropriated. According to the WRIA 49 Level 1 Assessment (ENTRIX, 2006), if quantities of major diversions, permits, and certificates are totaled, the appropriated flow greatly exceeds the mean annual flow in any of the tributaries. On Bonaparte Creek, for example, the mean annual flow is estimated to be 5 cfs, yet the appropriated flow including permits and certificates is 16.475 cfs, which is 330% more than the available flow. Similarly, Johnson Creek also has a mean annual flow estimated as 5 cfs, and has water rights and claims exceeding the mean average flow by 366%. In both these examples, however, there are several diversions above the stream gage, making it difficult to estimate actual diversion amounts and available water.

5.2. Effects of Storage on Water Budgets

Water storage projects located on any of the Okanogan River tributaries would operate similarly and affect timing of flows in similar ways. In general, water would be diverted into storage during spring months, March through May, at times when high snowmelt flows are present in the streams. The stored water would be delivered for irrigation purposes in July, August, and September. At other times of the year, the storage reservoirs would essentially operate “run-of-river”, meaning the outflow from the storage site will be equivalent to the inflow.

The major benefit of a storage project, either surface or groundwater, would be to capture excess flows at times when water is readily available, and to deliver flows back to the river later in the year at times when irrigation and in-stream needs are high. A secondary benefit would be an increase in the height of the groundwater table, which could decrease well pumping costs and increase discharge from groundwater into rivers, which may have positive effects on water temperature and habitat.

At this stage, not enough data are available to accurately quantify the effects that any individual storage project would have on its subbasin water budget. Additional data that would be required would include a record of continuous stream flow at or very close to the storage location, an assessment of water rights and records of upstream diversions, in-stream flow requirements, local evapotranspiration rates, water levels in wells, and infiltration rates of soils adjacent to the stream. In addition to hydrologic and climate data, physical characteristics of the storage project would need to be measured and calculated, including survey data near the proposed storage location, availability of construction materials, and the size of project features such as the crest length, height, and outlet works.

An assessment of the probable effects of surface storage projects and groundwater storage projects on the water balance in subbasins follows.

5.2.1. Surface Water Projects

Surface storage projects would likely operate by capturing high snowmelt flows during the spring for delivery back to the stream for irrigation purposes in the summer. Since it is unlikely that a storage project would be developed in the irrigable areas located in the Okanogan River floodplain, potential storage sites are generally located in the upper reaches of the tributaries. The quantity of water available varies greatly depending on the location in the watershed.

The west side of the Okanogan River Valley is located in the foothills of the Cascade Mountains and has steep terrain, higher precipitation rates, and greater impact from snowmelt runoff. Figure 5-1 shows an example of the effect of storage on mean monthly flows. The figure shows monthly flows measured at an Ecology gage located on Toats Coulee Creek near the town of Loomis and an example of how flows could be changed if regulated by a surface storage reservoir.

The east side of the Okanogan River Valley has some steep areas of terrain at the edge of the Okanogan River floodplain, but is generally much flatter and experiences much less precipitation. Evaporation rates will also be higher due to less vegetative cover and higher exposure to solar radiation. Ecology operates a stream gage on Bonaparte Creek near Tonasket. While a surface storage site is probably not feasible here, Figure 5-2 shows how a surface storage project at this location would impact the timing and delivery of flows.

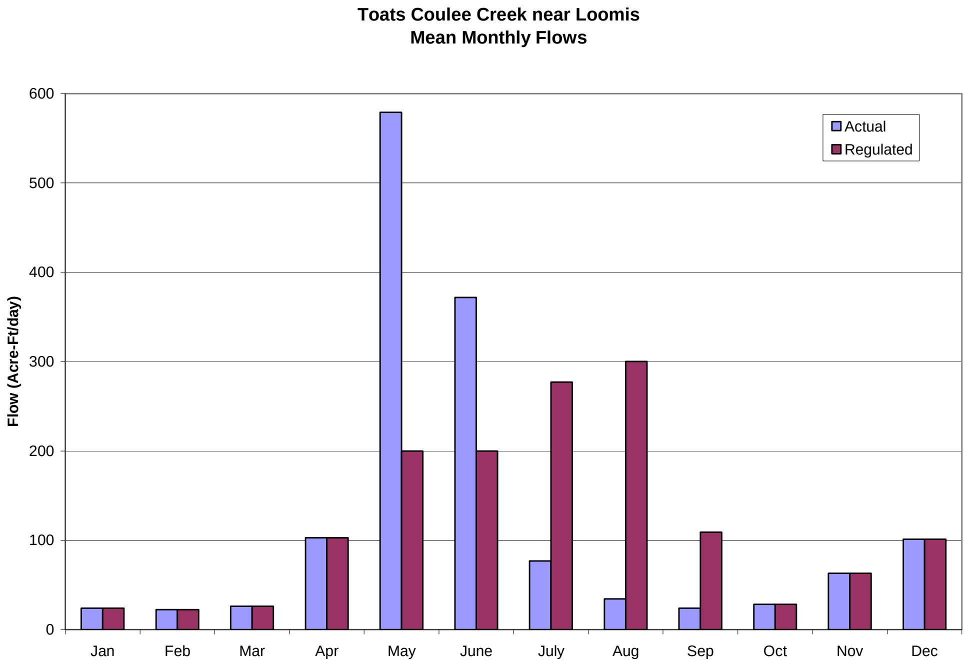


Figure 5-1: Mean Monthly Flows measured on Toats Coulee Creek near Loomis from 2003-2008, and an approximation of flows after regulation by a surface storage reservoir.

In addition to the affects of storage on timing of flows, evaporation from the reservoir can affect flows downstream of a storage project. Water that would otherwise flow downstream in the spring would be captured in a reservoir and exposed to a higher evaporation rate due a larger exposed surface area. The free-surface evaporation rate as measured at Conconully reservoir from 1956-1970 was 30 inches per year (Farnsworth *et. al*., 1982). During the months of May, June, and July, when the water is stored awaiting release, the total evaporation was estimated to be 15 inches.

Free-surface evaporation would decrease storage potential at any project and would vary proportionally with the surface area of the reservoir. For example, at Salmon Creek Site SA1, which is estimated to have surface area of 135 acres when full, 15 inches of water evaporating from the surface during May, June, and July would result in approximately 169 acre-feet of total evaporation, which is 5% of the total estimated storage.

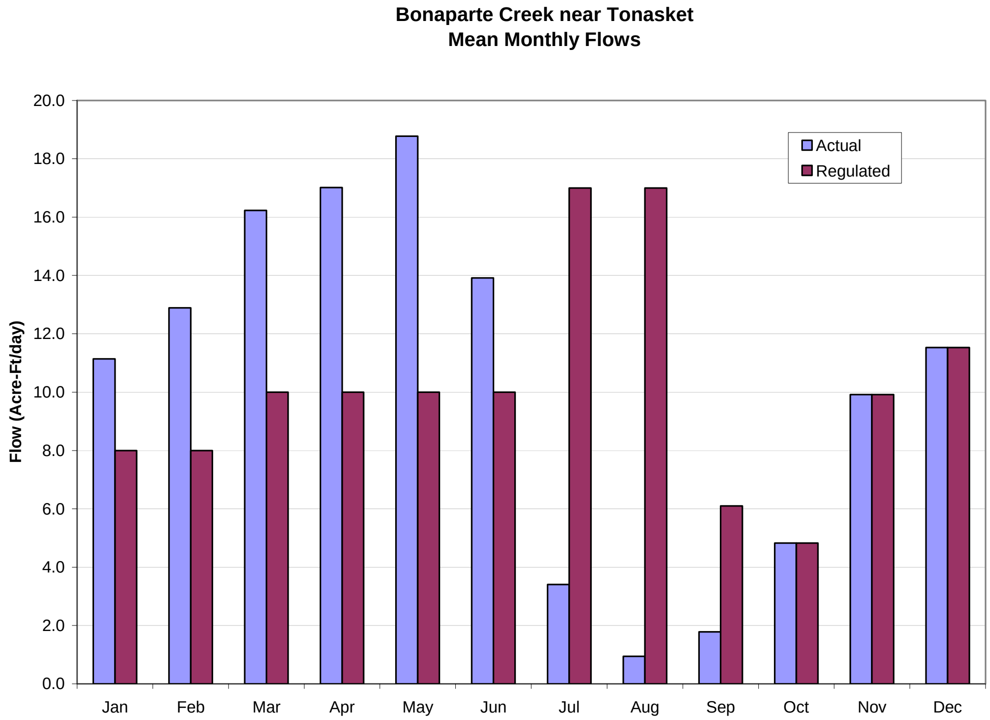


Figure 5-2: Mean Monthly Flows measured on Bonaparte Creek near Tonasket from 2003-2008, and an approximation of flows after regulation by a surface storage reservoir.

5.2.2. Groundwater Projects

The potential for achieving water storage by means of managed aquifer recharge is uncertain because of insufficient data. The most likely locations would be the lower Salmon Creek Subbasin and the upper Antoine Creek Subbasin. Of these, the lower Salmon Creek Subbasin area appears to have greater potential for managed aquifer recharge.

For both of these recharge locations, water would be diverted into settling ponds at times when flows are available, most likely spring months. Some of the recharged water would be returned by subsurface flows to the stream without recovery. However, a suitably positioned and distributed well field could potentially recover most of the recharged water for irrigation purposes. Alternatively, water could be delivered back to the stream for surface water deliveries in the summer. If subsurface flows can be predicted, the potential also exists to manage recharge so that water is allowed to return by natural subsurface flows back to the stream as a way of augmenting in-stream flows or controlling stream temperatures. Predictions of this sort, however, would require development and calibration of a numerical groundwater model.

5.2.3. Other Impacts

Modification to the timing of water flows through a storage project may have additional impacts other than a benefit to irrigation water supply.

Depending upon the geology of areas at surface storage sites, infiltration into groundwater may increase due to increases in inundated land. This effect may cause significant losses in surface supply during early years of operation, but is anticipated to decrease over time due to clogging, biological growth, and siltation in the reservoirs, which act to decrease infiltration rates. Infiltrated water would not entirely be lost, however, but would either bolster the ground-water table or simply return to the river downstream of the dam.

The capture and reduction of spring flood flows below storage projects may impact triggers for migrating fish that spawn in the tributaries. Also spring high flows that would normally flow overbank and recharge groundwater would now be stored which may have a negative effect on soil moisture during the spring in agricultural areas.

6.0 DISCUSSION AND RECOMMENDATIONS

6.1. Surface Storage

Small-scale surface storage projects may be possible along one of the tributaries to the Okanogan River. But in general, the opportunities are few due to topographical constraints in the tributary basins.

Most or all small surface storage projects would operate by capturing spring flood or snowmelt flows and returning them to the creek in late summer for water supply purposes. The dam structures would likely be earth-fill, although some could be concrete if suitable foundation and aggregate supplies can be found locally. It is also highly likely that some irrigable land would need to be obtained in order to develop storage, as most of the locations suitable for storage are already in use for grazing or agriculture.

The most promising locations for further research depend on both the cost per volume of storage and demand for the stored water. From a hydrologic standpoint, the best projects are located along the west side of the valley on Salmon Creek or Johnson Creek. However, it appears that basins on the east side of the Okanogan River have the most need for water. This would favor projects in the upper reaches of Bonaparte Creek or Antoine Creek. Existing water rights holders in the basin where a proposed project is located must be involved in the development of the project. Also, environmental restrictions may differ greatly from one basin to another.

At this stage, much additional information still needs to be collected to evaluate the feasibility of any surface storage project. Additional hydrologic and climate data such as stream flows and local evapotranspiration rates are required. A record of continuous stream flow at or very close to the storage location should be obtained. Other required data for analysis includes an assessment of water rights and in-stream flow requirements, the interaction with groundwater including infiltration rates of the soils, and records of upstream diversions and how they would impact the timing of inflow to the storage location. Once hydrologic and climate data have been collected, physical characteristics of the project site would need to be obtained including detailed survey data, geotechnical information regarding the dam foundation, and availability of construction materials. All of this information would be required to determine the optimal size of project features such as the dam crest length, dam height, and the size of the spillway and outlet works. Additional information required for a feasibility analysis is the demand for water, the added benefits of the project, and local support or sponsorship of the project.

The planning unit should employ local knowledge of water needs to select from among these projects. It is recommended that a program be developed to obtain additional data in the area of any project selected for further analysis.

Coordination with the Okanogan PUD concerning projects along the Similkameen may also present an opportunity to obtain water for local needs.

This report recommends that nine projects in six tributary basins are suitable for further investigation. These are described in Section 4.0.

6.2. Managed Aquifer Recharge

Some storage of water may be possible under a managed aquifer recharge program. The most likely location for this would be the lower Salmon Creek Subbasin near the mouth of the canyon and would involve diversion of Salmon Creek water to infiltration basins. The next most likely location for a managed aquifer recharge facility would be in the upper Antoine Creek Subbasin. Existing data are insufficient to adequately evaluate the viability of a successful recharge program in either location, and important limitations have been identified in both locations that could limit or prevent a recharge program. The volumes that could be stored at either location are very preliminary. However, these areas look promising and should be evaluated further.

Additional data are required for a more complete and reliable determination of feasibility and quantities that could be achieved in a managed aquifer recharge program. These include the following:

- Borehole logs and laboratory tests to show soil types, grain size, and gradation from the surface to below the water table
- Well production capacities in the vicinity of each location
- Aquifer pumping tests near the probable locations of recharge and recovery
- Infiltration tests (field and laboratory) at potential infiltration basin sites
- Availability of suitable land for recharge facilities
- Availability of land for recovery wells
- Stream flows and minimum in-stream flow requirements over time in Antoine Creek and Salmon Creek near probable points of diversion
- Water rights availability in Antoine Creek and Salmon Creek
- Evaluation of probable points of stream flow diversion and alignments for gravity pipelines from diversion to infiltration basins
- Groundwater and surface water quality in the vicinity of proposed infiltration basins
- Numerical computer modeling of probable distribution of recharge water in the subsurface
- Numerical computer modeling of water quality blending to estimate probable reactions such as precipitation or dissolution of soils

It is recommended that a program be developed for evaluation of recharge potential at the lower Salmon Creek Subbasin location, including the data requirements identified above. Additional data needs may be identified during the evaluation. A program could also be developed for the upper Antoine Creek Subbasin, although the probability of success in this area appears to be lower.

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APPENDIX A
Field Visit Report

M E M O R A N D U M

MWH
MONTGOMERY WATSON HARZA

To:	Bob Clark, Okanogan Conservation District	**Date:**	August 30, 2008
From:	Dennis Dorratcague	**Reference:**	1520923

Subject: WRIA49 Water Storage Assessment
Field Visit Report

This memorandum contains the report of our Field Visit as outlined in Task 2.3 of our scope of work, and fulfills our requirement as outlined in Task 2.3.

Field Visit Report

Those performing the field visit were all from MWH. Their names and job functions on this project are given below.
Dennis Dorratcague: Project Manager
Dave Whitbeck: Surface Water Hydrology
Greg Rollins: Geotechnical Engineer
Pat Naylor: Groundwater Hydrology

The field trip was conducted on August 20 and 21, 2008. Two sites on the Similkameen River basin were visited on August 22nd while visiting the Shankers Bend project site for Okanogan PUD. A general description and timing of the work performed is provided below. The description of the observations from the field visit is attached and forms the major part of the trip report. The group had two vehicles Dennis, Dave and Greg were in one to visit the surface water storage sites. Pat Naylor was in another to visit the groundwater storage sites.

August 20, 2008

Time	Event
6 AM to 11 AM	Traveled to Omak.
11 AM	Met at Omak Inn and reviewed the list of sites and area maps.
11:30 AM	Departed for site visits.
12:15 PM to 1 PM	Lunch in Oroville
1 PM to 7:30 PM	Visited 10 potential surface water storage sites on Tonasket, Antoine, Siwash, and Sinlahekin Creek drainages. Visited 10 potential groundwater storage areas on Tonasket, Okanogan, Antoine, Siwash, Aeneas, Omak, Tunk drainages. See attached.

August 21, 2008

Time	Event
7:30 AM	Depart Omak.

8:00 AM to 1 PM	Visited 7 potential surface water storage sites on Bonaparte, Tunk, and Omak Creek drainages. Visited 4 potential groundwater storage areas on Sinlahekin, Salmon, Okanogan drainages. See attached.
1 PM to 2 PM	Lunch
2 PM to 3 PM	Meet with Bob Clark at Okanogan Conservation District Office
3 PM to 5 PM	Visit 3 potential surface water storage sites on Salmon Creek.

August 22, 2008

Time	**Event**
11 AM to 12;30 PM	Visited Nighthawk and Palmer Lake potential surface water storage sites

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cc: Jeremy Pratt, ENTRIX

WRIA 49 Water Storage Assessment
Notes from Field Trip to Possible Sites

Start: August 20, 2008
End: August 21, 2008

Personnel: Dennis Dorratcague, PM; Dave Whitbeck, Surface Water Hydraulics and Hydrology; Greg Rollins, Geotechnical & Soils; Pat Naylor, Groundwater Hydrology and Recharge

These are the combined notes of all participants on the trip. The notes are in two parts. The first is notes for the possible surface storage sites. The second is of the notes for possible groundwater storage opportunities. Each of these two parts is divided into the two days of the field trip, August 20 and 21.

The surface storage sites were visited by Dennis Dorratcague, Greg Rollins and Dave Whitbeck. Pat Naylor traveled separately to visit possible groundwater storage opportunities.

SUMMARY OF SURFACE WATER STORAGE SITE RECONNAISSANCE

Prior to the field trip, possible surface storage sites were identified from a review of topographic maps. These sites were identified as to the subbasin by a two-letter identifier and a consecutive number indicating the sites within that basin. For example, TN-1 is the site number 1 within the Tonasket Creek subbasin.
The notes below are the combined filed notes of the three people visiting the site. The notes are color coded as to the author of the notes.

- Dennis Dorratcague - black
- Dave Whitbeck - blue
- Greg Rollins - green

Photos were taken at most of the sites for our files. The photo numbers for each day are indicated in the first bulleted comments under each site.

August 20, 2008

- TN-1
  - No abutment, rock or storage volume behind dam.
  - Steep gradient in the lower reaches of the river imply very little storage.
  - No good abutments, all glacial till.
  - Limited storage at this location; Glacial drift abutments; Right abutment is very gradual (no real distinguishable abutment); no rock in the abutments. Earthfill is likely only option.

- TN-2
  - 1-4 Dam, 5 Reservoir
  - ,No rock foundation, earth-fill dam required, limited storage
  - Could potentially have a wide earth-fill dam at this location.
  - Would have to relocate the road.

- Could be issues with lack of reasonable water supply at this location to validate construction of a dam.
- Long dam would be required; no real distinguishable right abutment; right abutment may not be suitable geotechnically; 60 to 80 ft. high dam max.

- AN-1
  - Did not visit this site due to lack of access.
  - According to topography maps, a dam at this location would back water into the Antoine valley, and may even flood into Siwash Creek.
  - Very limited storage due to steep terrain.

- AN-2
  - 15 at the dam site, 16-18 DS to US at Dam site; 19, 20- right and left at abutments; 21, no trespass sign
  - 60'-80' dam
  - Sufficient water is a question
  - Amount of storage is unknown
  - Could not access site – no trespass sign
  - No access except form a dirt road.
  - Classic dam shape and good rock abutments.
  - Plenty of local dirt that could be potentially used for an earth dam.
  - No water in creek at the time we looked at it.
  - Reservoir would inundate a couple of farms and ranches.
  - Possible dam would be 300-500 feet in length; fractured rock observed on both abutments; earthfill or RCC dam might be possible; valley floor appears to be suitable source of core material for earthfill dam; Enough water to fill reservoir appears to be a potential issue.

- AN-3
  - 6-8 Dam panorama, 9, 10 Dam and Reservoir, 12-13 spillway from right abutment, US to left
  - Promising Site to add to the existing dam
  - Hard to tell the extent of existing dam
  - Could not find outlet works
  - 30-40' high, Dam possibly out another 20' LT ? Abutment's, sandy till, doesn't look like it fells up. Leaky abutment? Leaky Dam! Right abutment Earth CA ?. Spillway with extra earthen fuse plug.
  - An existing dam is present at this site which irrigates the farms in the surrounding area.
  - Dam could be raised by moving left abutment over to roadway.
  - Very little of rock in the area.
  - Dam may have issues with water supply, but existing dam appears to be leaky.
  - Information from Bob Clark indicates that water rights may be over-allocated already and increasing a dam height in this area may prove ineffective for obtaining surface storage.
  - Existing dam possibly 30-40' high; topographically it looks possible to raise dam another 20 ft.; Left abutment is possibly sandy glacial drift; Appears that reservoir rarely fills up without any observed outlet. May be a leaky dam. Topography drops substantially beyond right abutment, perhaps the right abutment is leaky. Earthfill dam or dam raise at this site.

- SW-1
    - 25 Dam Site From upstream on right "shoreline"; 26-30 Panorama from dam site to left showing reservoir
    - Need to relocate farm house and out buildings and Tonasket-Havillah Rd. and the distribution power lines.
    - Good shape for high dam.
    - Rock exists that may support a concrete dam, but earthfill may be more likely.
    - Topography favorable for a high dam. Rock on left abutment appears to be meta-igneous. Right abutment is glacial till overlying rock. Appears to be good storage potential; Road would require relocation. Earthfill or possibly RCC.

- SW-2
    - Too steep, no storage
    - Limited storage; not a good location
    - Rock appears suitable for a dam, but gradient is so steep that there would be very little storage.
    - Very limited storage; not a good dam location

- SW-3
    - 22,23, Looking U.S. at Dam site and reservoir area; 24, creek, DS of Dam Site
    - 2 cfs ± in the creek.
    - Creek is incised 20' into a flat valley
    - Very shallow valley: no storage, or long, long dam. Silt till; not a suitable site.
    - Not much water present due to location in upper reaches of creek.
    - No good foundation rock and an earth-fill structure would have to be excessively long.
    - Would not put a dam here.
    - Very shallow valley: Not much storage unless a very long dam is constructed; Abutments appear to be silty till; Not a suitable site.

- TC-1
    - 31 and 32 Diversion below site; 33-35 looking DS left to right; 36 to E. down Toats Coulee
    - Good site in a canyon above the road.
    - Could extend above road to get more storage.
    - All sites in Coulee are good, narrow, rock. However, no storage due to stream gradient.
    - In recreation area, many campgrounds, etc.
    - USCG6 13M D 394 1959 High energy creek boulder to 6 + ft. in stream bed; steep narrow canyon 120-150' high to road. 400' across. Meta granitic ? Req., limited storage
    - Very steep canyon.
    - Dam could easily be 200 ft high.
    - Good rock on both sides may be suitable for concrete dam.
    - River is so steep that is would probably not provide sufficient storage compared to height.
    - Benchmark at site: USCG6 13M D 394 1959 High energy creek boulder to 6 + ft. in stream bed; steep narrow canyon; good abutments; dam height would be 120-150' high to road elevation; about 400' long at this elevation. Meta-granitic rock exposures on left abutment, with widely spaced joints; some slide debris and weathered material; hard to estimate how much excavation would be required. Limited storage available.

- SN-2
  - 37-40 Looking up stream. (left abutment in photo 37, right abutment in 40).
  - Large drainage area of 90 sq. miles and relatively flat valley for storage.
  - Have to reroute the road.
  - RT abutment till (silty) LF Abutment glacial, over 600' long, 15' up to road; another 40' long, possibly RT abutment soil, no sign of slide; LT abutment suspect pretty good storage. Some springs noted in RT abutment till. Valley within 1 cn. Rock RT.
  - Roadway sits 15-20 ft above creek.
  - Dam could be very tall, potentially 100 feet high, but would flood the Sinlahekin Wildlife Area.
  - Road would need to be relocated, which may be an issue.
  - Right abutment is silty glacial till; Left abutment glacial outwash or possibly esker; dam would be over 600' long. About 15' up from creek to road; dam could possibly be another 40' high above the road. Right abutment would be soil, no sign of slide; Left abutment may not be suitable. Pretty good storage. Some springs noted in right abutment till. The valley walls are igneous rock; but prohibitive excavation would be needed to tie into rock abutments on each side.

- TC-2
  - Several areas suitable geo technically for high Dam, Concrete, high gradient, low storage. Recreation areas.
  - Several sites in region, which also has very high, steep cliffs.
  - Probably not much storage due to high gradient.
  - Located in recreation area.
  - Several areas suitable geotechnically for high concrete gravity or arch dam; stream has very high gradient and storage would be low.. Dam/reservoir would encroach or inundate recreation areas.

- SN-3
  - 41, 42 Across Dam centerline ; 43 DS down valley; 44 US up valley, reservoir in lower left of photo
  - Possible concrete arch dam – construction by tram overhead.
  - However, small amount of storage.
  - Very steep abutments. Rock exposed several places, some excavation required. Arch
  - Very steep canyon.
  - River appears to be of less gradient than SN4 or SN5.
  - Rock appears to be suitable for a concrete dam.
  - Access to dam site is remote and bringing in material may be difficult.
  - Very steep abutments. Rock exposed several places, some excavation required. Suitable for arch on concrete gravity dam. Gradient appears less steep than gradient than sites SN 4 and 5. Construction access and diversion would be difficult. View of dam site limited from the road due to trees.

- BP-1
  - Can't do dam in lower reaches because you would have to relocate Hwy 20.
  - Rock US is good.
  - Further up the creek the land starts to level out for more storage, but the abutments are in till. So, earth-fill dam required.
  - Areas near the Okanogan River are also the somewhat populated.

- Lower area of river has plenty of good rock which may be suitable for a concrete dam, but gradient is so steep that there would be very little storage.
- Bonaparte lower reaches; Rock abutments, metamorphosed rock with joints and fractures. Length of dam would be short. Steep canyon with steep stream gradient and therefore little storage: Relocation of Hwy 20 would be required; Possibly RCC.

August 21, 2008

- BP-2
  - 1-3 looking US left to right abutment.
  - Large dam, probably not enough water.
  - Potential site exists right as river comes out onto the plain, although valley is highly developed with agriculture.
  - Site would provide a high amount of storage due to the width and shallow gradient of the valley.
  - Site would likely require a long earthfill dam.
  - Bonaparte just downstream of Bannon Creek; Right abutment consists of highly jointed basalt; left abutment may not be suitable; dam hear could be 100 feet high and possibly 2000 feet long. Earthfill.

- BP-3
  - 4-6 D.S. at site from right abutment to left.
  - Relocate one house just upstream.
  - Limited storage.
  - Dam could supply water to areas of valley.
  - Small creek; Left abutment is probably rock (view obscured), dam could be 40' high, 400' long. May require relocation of Hwy 20. Right abutment may not be suitable; Steeper creek gradient and therefore less storage; Earthfill.

- BP-4
  - 7-10 looking downstream from right to left abutment.
  - Any of the moraines across the valley in the valley upstream.
  - Utilize moraines.
  - Moraine deposits exist along one side that may provide decent abutment for an earthfill dam.
  - Material is till, however, and may provide suspect abutments.
  - Dam at this location may have issues with leakage.
  - Sites where valley appears up and apparent moraine or esker partially crosses valley; Left abutment outwash or esker with granular soils – would need treatment prior to storing water; Right abutment is likewise less than ideal; No visible outcrops of rock; Relocate Hwy 20; Earthfill dam.

- BP-5
  - 11,12 looking DS right to left abutment.
  - Have to relocate Hwy 20 as with all BP alts.
  - Pretty good reservoir volume.
  - Rock abutments on both side of road could support a dam up to 100 feet high.
  - Road would have to be relocated.

- Good topography for dam and reservoir (opens into fair sized valley); Right abutment outwash(?); Left abutment in okay condition; relocate Hwy 20 required. Earthfill dam.

- BP-6
  - 13 looking upstream at dam site which would go across along tree line.
  - Good reservoir area.
  - One or 2 house & out-buildings relocation.
  - Earth fill dam.
  - Bona parte recreation area upstream.
  - Relocate Bone parte Lake Road.
  - Good rock knob exists right as the Bonaparte Creek comes out of the valley and combines with another tributary.
  - Dam could be 40-50 feet high.
  - Shallow valley would provide good storage.
  - Would require relocation of some facilities in the recreation area.
  - Near intersection of Hwy 20 and Bonaparte Lake Road. Good abutments (soil over rock; some excavation required); Topography is good as Bonaparte Creek meanders upstream. Need to check geology publications for the abutments. Dam could possibly be 50-80' high. Earthfill dam; Requires relocation of Bonaparte Lake Rd.

- TU-1
  - 14 Dam site, 15,16 left and right northward.
  - Rock fill Dam.
  - Good storage upstream
  - Limited storage; Till abutment; no real right abutment
  - Steep rock in area, implying very little storage present.
  - Rock appears suitable for dam in the lower reaches of the river, but probably would not put one here.
  - Fairly high gradual-gradient valley; Glacial drift abutments; 150' high earthen dam; Suitability of abutments is questionable; Doubts about the amount of water available to fill reservoir.

- TU-2
  - 17-20 looking DS from right to left abutment.
  - In 17 dam centerline starts above car on road and extends across upstream ranch building.
  - Dam could be above or below the road. See 17
  - 60'-80' hight max; Long Dam weak Right abutment;
  - Pies 1-4 Dam, 5 Reservoir
  - Very little water apparent in area due to location in headwaters of the creek.
  - Wide, flat valley present may be suitable for an earthfill dam.
  - Valley upstream couled potentially provide adequate storage, if water were available.
  - Would have to relocate 2-3 farmers. Dam would be very long.
  - Valley in glacial drift. Pinch point 40-60' high. 600' across. Abutments both appear to be sandy glacial formation; Topography is fair to poor. Earthfill dam; Doubts about the amount of water available to fill reservoir; Fair to poor site.

- OM-1
  - Did not visit this site. No access from roads.

  - Located on Colville Reservation.
  - Banks further upstream on Omak Creek implicate that an earthfill dam would probably be the most suitable for this site, if feasible. Omak Creek is probably off limits, however. The Colville Tribe has previously spent money trying to get the river to flow, and is actively trying to figure out how to get fish back in it.

- OM-2
  - 21,22 looking upstream at left and right abutment, respectively; 23 of bridge over creek.
  - Good flow in creek 2-3 cfs.
  - 30-40' high earth dam.
  - On Colville reservation
  - Existing access from a primitive road, location on Colville Reservation.
  - Plenty of water appeared to be flowing, even in late August.
  - River at this location was entrenched in a small valley with relatively high presence of vegetation.
  - Site would probably be suitable for an earthfill dam approximately 30 feet high.
  - (Near bridge down Dutch Anderson Rd.) Abutments appear to be soil. 30-40' high earthfill dam; Would be less than 200' long; Seems to be plenty of water. Storage seems limited.

- SA-1
  - 24-31 at Existing Diversion; 24 Existing Dam; 25-27 right and left abutment of proposed higher dam; 28 look downstream in canal; 29-31 Fish passage weirs.
  - Road would have to be relocated up hill to accommodate higher dam.
  - Fish screening and passage must be provided.
  - An diversion dam exists at this site that essentially diverts all of the flow from the river
  - River valley has very steep side walls and a dam could be built that is easily 50-60 ft high.
  - Dam at this location would likely require relocation of the road and it was unclear where it could be relocated to.
  - Water rights may be an issue. Water is likely diverted from Conconully reservoir and fed by local tributaries. Further analysis is needed to determine if a suitable amount of water is present at this location for a surface storage project.
  - At an existing diversion; Left abutment weathered igneous rock; Right abutment soil; Possibly raise storage another 10 feet high with earthfill dam, possibly higher with relocation of Salmon Creek Rd. Right abutment is sandy till with silt and cobbles/boulders.

- SA-2
  - 34,35 D.S. at dam site at lift abutment (34) and toward right abutment, which is obscured by trees.
  - Major problem with road relocation.
  - Have to work out water rights delivery to Lake Conconully.
  - Site located upstream from Conconully reservoir along a road with numerous vacation homes and recreation areas.
  - Steep rock in area, and a rock knob suitable for a dam appeared to be located at the confluence of the west and south forks of Salmon Creek.
  - Steep gradient as indicates that a dam at this location will have little storage.

- In addition to relocation, the ability to deliver and use any surface storage past Conconully reservoir and to the Okanogan would be difficult to manage and monitor.
- Canyon just downstream of the confluence of the North and West Fork Salmon Creek; Left abutment has igneous rock exposed, highly fractured and slightly weathered; Right abutment is hard to see; some exposed rock. Left abutment will need grout. Very likely a rock foundation, so RCC dam is probable; Major relocations of road and residences required.

- SA – 3
  - 32,33 Dam site;
  - This area in foreground of 32 appears to be a closed basin. Therefore, SA-2 is not a good site since discharge from the dam cannot make it out of the basin.
  - Site has a classic rock foundation for a dam, but no flow exists in river here.
  - Site may be located in an enclosed sub-basin and may experience flows in both directions at different times of the year.
  - Eliminated from further consideration.
  - Big basin; near head waters of Johnson Creek; no notable flow. Not a suitable site.

- SM-1
  - Dam would be long earthfill and would be very wide.
  - Valley upstream would provide for a lot of storage, but would also flood out irragable land and wetlands.
  - Similkameen River at Nighthawk; Really only suited for higher dam (150' or higher); Dam would be very long dam; Earthfill likely most suitable; Substantial excavation along abutments would be required and possibly abutment grouting.

- SN-1
  - Railroad embankment crossing river could be modified or a new dam could be constructed right at the downstream end of the lake.
  - In either case, will require a long, earthfill dam that may be a mile wide.
  - Dam will flood wetlands located in littoral zone of lake.
  - Depending on height and location, dam may flood houses and orchards along shoreline.

- J1 & J2
  - Did not visit these sites. Bob Clark from the Okanogan Conservation District identified that these sites would probably have limited to no value because they drain into the Columbia River and most or all of the water rights holders in the basin draw from the Columbia River, not the Okanogan River.

SUMMARY OF GROUNDWATER STORAGE SITE RECONNAISSANCE

August 20, 2008

- Tonasket Creek Sub-basin (GW Site 1)

  - Near surface sites OS14, OS15
  - Shallow soils with abundant rock outcrop on canyon walls
  - Mostly narrow canyon/drainage

- Stream channel through alluvium likely to receive the limited groundwater recharge occurring in drainage
    - Limited alluvium above stream elevation, limited potential groundwater storage volume
    - Substantial silt component in surface soils, likely low permeability

- Okanogan River Valley between Oroville and Ellisforde (GW Site 2)
    - Gravelly sand surface soils in road cut on Highway 97, near mile marker 325, ~3 miles N. of Ellisforde (Photos G2, G3)
    - Possible infiltration potential at elevation above river
    - Quickly falls off to floodplain (20-30 ft lower); would seep or recharge to river W. of highway
    - Wetlands in valley floor/floodplain between mile markers 324-323, just south of this area

- Okanogan River Valley between Ellisforde and Tonasket (GW Site 3)
    - Gravelly fine sand surface soils in road cut on Highway 97, near mile marker 319
    - Approx. ¼ mile E. of Okanogan River, ~3 miles S. of Ellisforde in general vicinity of Surface Site OS11
    - 20-30 ft above floodplain
    - Limited groundwater storage capacity between E. edge of valley and E. edge of floodplain/Okanogan River

- Antoine Creek Sub-basin (GW Sites 4 and 5)
    - Mixed agricultural and forest/range use land (agriculture on flatter lowlands)
    - Fine gravelly sand typical on surface and in road cuts (Photos G4, G5, G6)
    - Sub-basin may have some groundwater storage capacity because of large wide alluvial valley floors between OS12 and OS13; possibly also between OS 11 and OS12, although this area more likely to have limited storage volume due to lower elevation above Antoine Creek
    - Flat sub-basin floors suggest some fines may be deposited in floodplain in subsurface (need to verify from well logs)

- Siwash Creek Sub-basin (GW Site 6)
    - Narrow canyon area near OS10
    - Steep canyon walls
    - Rock outcrops in canyon walls
    - Mostly silty soils
    - Limited alluvium above stream elevation, limited potential groundwater storage volume

- Bonaparte Creek and Aeneas Creek Sub-basins (GW Site 7)
    - Some granular soils in valley floor
    - Limited alluvium above stream elevation, limited potential groundwater storage volume

- Okanogan River Valley between Tonasket and Omak (GW Site 8)
    - Rough benches above flat floodplain of Okanogan River
    - Gravelly sand soils in several road cuts, especially between mile markers 308-304 (near confluence with Tunk Creek)

- Lowland ponds indicated groundwater table not far below surface, recharge would tend to flow to ponds on W. side of valley floor and/or to river floodplain on E. side of valley floor
- Some limited groundwater storage capacity in-between but would likely result in substantial losses to surface water before recovery from wells possible

- Omak Creek Sub-basin between Omak and upper French Valley area (GW Site 9)
  - Near surface sites OM1, OM2, and downstream from there
  - Silty gravelly sand soils in canyon floor
  - Some agriculture (crops and pastureland)
  - Extensive bedrock outcrops in canyon walls and in some places in valley floor
  - Steep canyon walls in many places
  - Geomorphology suggests limited potential volume for groundwater storage

- Tunk Creek Sub-basin (GW Site 10)
  - Near surface sites OS1, OS2
  - Limited private road access
  - Narrow canyon, shallow soils, rock processing facility near mouth of canyon
  - Soils appear to have moderate to high silt content, probably moderate to low permeability
  - Flat, narrow floodplain just above elevation of creek
  - Limited alluvium above stream elevation, limited potential groundwater storage volume

August 21, 2008

- Sinlahekin Valley (GW Site 11)
  - Narrow valley with limited agriculture (crops and pastureland)
  - Steep canyon walls
  - Limited alluvial volume in valley floor above stream elevation, limited potential for groundwater storage volume (Photos G7, G8, G9)
  - Fine gravelly silty sand soils
  - Discharge to streams, wetlands, ponds

- Salmon Creek Sub-basin near Concully (GW Site 12)
  - Near surface sites SA1, SA2
  - Generally narrow valley and tributaries
  - Limited alluvium above stream and pond elevations, limited potential groundwater storage volume

- Salmon Creek Sub-basin between DeLorme and Okanogan (GW Site 13)
  - Narrow canyon with limited agriculture (mostly pastureland)
  - Steep canyon walls with rock outcrops
  - Some gravelly sand soils with some silt at surface
  - Limited alluvium above stream and pond elevations, limited potential for groundwater storage volume in upper part of sub-basin
  - More alluvium in terraces above Okanogan area, possibly greater volume for groundwater storage, but would still would be limited storage volume with losses to Salmon Creek and Okanogan River valley floor, floodplain, and/or river, would require recovery well line between recharge basins and lowlands

- Okanogan River Valley S. and SW of Okanogan (GW Site 14)
    - Valley floor soils mostly agriculture, wetlands, or floodplain
    - Gravelly silty sand in road cut (Photo G10)
    - Most areas have limited alluvium above floodplain, stream and pond elevations, limited potential for groundwater storage volume
    - Terrace areas along margin of valley have a little more storage volume but would report to lowlands unless recovered by barrier of wells