LAKE CHELAN WATERSHED PLAN (WRIA 47)

FINAL
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Prepared for
WRIA 47 – LAKE CHELAN WATERSHED PLANNING UNIT

Lead Agency CHELAN COUNTY NATURAL RESOURCES DEPARTMENT
Wenatchee, Washington

Prepared by
RH2 ENGINEERING, INC.
East Wenatchee, Washington

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Preamble to the Lake Chelan Watershed Plan

Lake Chelan is unique.

Examples of Lake Chelan uniqueness include very high water clarity and quality, lake depth, active reservoir management, combined native and introduced species fisheries, and glacial contribution to runoff. While all waterbodies have their own distinct characteristics, Lake Chelan presents a special set of circumstances that may not lend itself as easily to scientific conclusions developed from studies conducted on other waterbodies about aquatic habitat needs, land use impacts and fisheries management issues. There is broad acknowledgement that Lake Chelan has been altered by the construction and management of the dam constructed on the Chelan River; extirpation of a native species; introduction of a variety of aquatic species; and substantial development of recreational, residential and commercial activities, particularly in the lower Wapato basin. Though these changes to Lake Chelan are well-documented, a broadly-accepted set of management actions for Lake Chelan based on Lake Chelan-specific research has not been developed to the extent desired by some. The Lake Chelan Watershed Plan (LCWP) attempts to address many of these issues.

A number of studies of aquatic habitat, water quantity, water quality, and fisheries conditions have been conducted in the watershed since the late 1970s to collect preliminary watershed information or to support specific data gathering objectives. Even with these studies, many gaps in understanding of specific conditions in the watershed still remain. Lake Chelan management agencies have considered the findings of water quality and habitat studies for other similar lakes (e.g., Lake Tahoe) to support the development of management programs for Lake Chelan, which, as stated previously, may not reflect as accurate conclusions as desired for Lake Chelan aquatic and terrestrial resources.

Because of the unique characteristics of Lake Chelan, during the preparation of the Phase 4 Detailed Implementation Plan, the Planning Unit will identify and develop specific study needs based on the recommendations in this watershed plan. These Lake Chelan specific studies will address unique conditions in Lake Chelan to promote the establishment of as sound management decisions as practicable. For example, the following questions regarding Lake Chelan management could be more readily understood through additional Lake Chelan-specific studies and policy consideration.

1. What are the effects, if any, of over-water and shoreline structures on aquatic habitat and aquatic species in Lake Chelan?
2. How should permitting for proposed new structures address these effects, if any?
3. What is the appropriate fisheries management plan for Lake Chelan given the various introductions and extirpations of aquatic species?

The following Lake Chelan Watershed Plan (WRIA 47) is intended to identify key findings and challenges facing watershed planning and recommend specific actions to address the key findings and challenges. The ultimate goal of the LCWP is to provide a locally based management document to assist in managing and protecting the natural resources of the Lake Chelan watershed. Based on Lake Chelan specific knowledge and understanding the Phase 4 Detailed Implementation Plan will provide the framework for management decisions and actions to be implemented.

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From 1991 to 2007, water quality planning activities were conducted by the Lake Chelan Water Quality Committee (LCWQC), which included Chelan County, the City of Chelan, the Lake Chelan Sewer District, the Lake Chelan Reclamation District, Chelan PUD and the U.S. Forest Service. The LCWQC was involved with several water and environmental quality studies and activities in the basin. This included the implementation of actions within the areas of sanitary sewage collection and treatment, on-site sewage disposal standards, stormwater facilities, boat pump-out stations, agricultural best-management practices, water quality monitoring and public educational programs.

In October 2007, the Lake Chelan Watershed Planning Unit (LCWPU) was formed, largely by members of the LCWQC, and has continued the objectives and activities of the LCWQC under the Watershed Planning Act, RCW 90.82.

Since October 2007, the LCWPU has conducted Phase 1 Organization Planning, Phase 2 Water Quantity and Quality Assessments, and a Habitat Assessment. The LCWPU has developed this Phase 3 Watershed Plan to compile the findings of the assessments and recommend actions that will meet the watershed planning objectives of the LCWPU. During Phase 4 Implementation, starting in 2012, the LCWPU will evaluate and prioritize the recommendations and proposed actions.

The LCWU established the following key objectives during Phase 1

- Assess water supply, use and projected needs.
- Develop and implement a comprehensive, long-term monitoring program of key parameters that will ensure water quality sustainability throughout the Lake Chelan Watershed.
- Address water bodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.
- Inform and educate local communities and visiting populations about water quality protection.
- Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources

The LCWU developed the following findings and challenges during Phase 2, and proposed recommended actions for the Lake Chelan (WRIA 47) Watershed Plan:

Water Quantity

Findings and Challenges

- Most of the physically available water entering WRIA 47 is discharged through Lake Chelan and used for power generation.
- Water is available for appropriation subject to the terms of the 1992 Agreement between Chelan PUD and the Washington State Department of Ecology, and the 2006 renewal of the FERC license for the Lake Chelan Dam.
- Irrigation water use is very efficient and the incremental improvements in irrigation efficiency are unlikely to significantly increase water availability in the basin.
- Much of the domestic, commercial and industrial water use either returns as base flow seepage into Lake Chelan, or discharges to the Columbia River as treated wastewater; these beneficial uses are a minor component of water balance.
- Conversion of lands and beneficial uses of water in the Wapato, Manson and lower Lucerne sub-basins from irrigation to domestic use will affect groundwater recharge, base flow, and water quality in these sub-basins.
- Current water use and estimates of future water use in the Wapato, Manson and lower Lucerne sub-basins are based on limited documentation of actual beneficial uses and return flows.
- Predicting changes in water use requires additional data and analysis to quantify beneficial use and return flow estimates to support water quality modeling, water use planning, and watershed management.

Recommended Actions for Water Quantity

- Improve the documentation of beneficial water use, inchoate rights, pending applications for new water rights, existing municipal water supply, irrigation water use, and irrigation return flow to update water balance estimates and monitor the effects of changes in water use to improve estimates of future water availability in WRIA 47.
- Initiate surface water and groundwater monitoring in the Wapato, Manson and lower Lucerne sub-basins to provide data to support water quality and habitat monitoring and improvement plans in WRIA 47.
- Use improved water balance estimates to support implementation of water quality studies and water quality management.

- Promote joint comprehensive analysis and prioritization of future municipal/domestic use by large and small Group A systems, Group B systems, future irrigation use, and future commercial/industrial use.
- Evaluate regional growth patterns, regional demands, inchoate water rights and water system connections for future/expanded service areas.
- Evaluate potential future irrigation demands and transfers of water rights following conversion of agricultural land prior to transfer for other purposes.
- Obtain agreement from Ecology and the PUD regarding the amount of water available for appropriation under the 1992 Agreement (estimated at 20,000 acre-feet). Initiate cost-reimbursement processing of the pending new water right applications that may be covered by the 1992 agreement.
- Identify an adequate domestic water and fire-fighting supply as airport and planned developments proceed in the Howard Flats subbasin.

Water Quality

Findings and Challenges

- Water quality concerns within WRIA 47 include elevated concentrations of organochlorine pesticides, PCBs, and dioxins/furans in fish tissues, and elevated water quality constituents including phosphorous, pH, dissolved oxygen, and invasive exotic plants.
- A Total Maximum Daily Load (TMDL) for phosphorous in Lake Chelan was approved by Ecology and EPA in 1993.
- A TMDL for DDT/PCB in fish tissues in Lake Chelan was approved and completed in 2006.
- Monitoring fish tissue concentrations is the primary strategy to track progress of the implementation of the TMDL for DDT/PCB.
- Water quality monitoring data for WRIA 47 include few consistently measured parameters, which limits the ability to discern trends in water quality in WRIA 47.
- Developing and implementing a Long-Term Monitoring Plan (LTMP) for Lake Chelan would meet the effectiveness monitoring requirements and implementation objectives of the TMDLs.

Recommended Actions for Water Quality

- Calibrate the QUAL-2K water quality model with the first year of data to initiate the LTMP
- Prepare a Quality Assurance Project Plan (QAPP) for the food web bioaccumulation model to support the characterization and monitoring objectives of the LTMP.

- Initiate the LTMP using the initial modeling results to advance the implementation of the TMDLs for phosphorous and DDT/PCB.
- Evaluate the feasibility and benefits of including benzene as part of the Long Term Monitoring Plan.
- Inform and educate agencies and the public regarding LTMP objectives and findings to support watershed protection in WRIA 47.
- Evaluate the feasibility and priority for extending sanitary sewer to rural areas along the North and South Shores and around the Manson Lakes.
- Evaluate the feasibility and benefits for establishing an On-site Wastewater Management District to improve rural septic system performance in removing both bacteria and nutrients.
- Evaluate the feasibility and benefit of managing irrigation drain return flows that discharge to surface water.
- Promote land use practices and regulations for stormwater and clearing/grading to reduce unmanaged stormwater and sediment discharge to surface water.

Habitat

Findings and Challenges

- Fish population impacts include habitat degradation and loss; land development, conversion, and management; agricultural practices; fish-passage barriers; dam operations; flooding; species introductions; interspecific breeding; competition for resources; disease; harvest; and hatchery and stocking operations.
- Historic and current land use practices, which disturb or modify natural habitat functions, have consequently altered water quality and/or quantity and availability and quality of habitat.

Recommended Actions for Habitat

- Support the Lake Chelan Fishery Plan (LCFP) objectives to improve understanding of Lake Chelan fisheries and fisheries management, and address competing management approaches.
- Support the monitoring and understanding of habitat and species interactions and reproduction by coordinating LTMP activities with Lake Chelan Fishery Forum (LCFF) activities to implement the LCFP.
- Support habitat restoration efforts to improve limiting factors for both fish and wildlife.
- Support developing a detailed implementation plan that includes prioritized fish and wildlife actions.

1.0 INTRODUCTION

Watershed Planning in Washington - RCW 90.082.010

The legislature finds that the local development of watershed plans for managing water resources and for protecting existing water rights is vital to both state and local interests. The local development of these plans serves vital local interests by placing it in the hands of people: who have the greatest knowledge of both the resources and the aspirations of those who live and work in the watershed; and who have the greatest stake in the proper, long-term management of the resources. The development of such plans serves the state's vital interests by ensuring that the state's water resources are used wisely, by protecting existing water rights, by protecting instream flows for fish, and by providing for the economic well-being of the state's citizenry and communities. Therefore, the legislature believes it necessary for units of local government throughout the state to engage in the orderly development of these watershed plans.

1.1 WRIA 47 WATERSHED PLANNING PROCESS

1.1.1 Four Phases of WRIA 47 Watershed Planning

The Watershed Planning Process, established by the Watershed Management Act in 1998 (RCW 90.82), includes the following four phases.

Phase 1, Organization: The initial phase, in which the initiating governments establish a Planning Unit and determine the scope of the planning was conducted by the Lake Chelan Watershed Planning Unit (LCWPU) from October 2007 to January 2008. Water quality planning activities were conducted by the Lake Chelan Water Quality Committee (LCWQC), which included Chelan County, City of Chelan, Lake Chelan Sewer District, Lake Chelan Reclamation District, Public Utility District #1 of Chelan County (Chelan PUD) and the U.S. Forest Service. The LCWQC operated from 1991 to 2007, and was involved with several water and environmental quality studies and activities in the basin. This included the implementation of actions within the areas of sanitary sewage collection and treatment, on-site sewage disposal standards, stormwater facilities, boat pump-out stations, agricultural best management practices, water quality monitoring and public educational programs. The LCWPU is largely formed by members of the LCWQC to continue the objectives and activities of the LCWQC.

The LCWPU concluded that certain sub-basins[1] would be included in the water quantity assessment but not in the watershed planning, as other agencies were adequately managing watershed conditions in the other sub-basins. Watershed conditions in the Stehekin and Railroad sub-basins are managed by the National Park Service.

Phase 2, Watershed Assessment: The technical analysis phase of watershed planning includes a required water quantity element and optional water quality, instream flow, habitat and water storage elements. The assessments compile and enhance local

[1] The term "sub-basin" used in this report and in watershed planning is defined as a geographic portion of a management area, defined by the watershed planning unit, on the basis of hydrologic or hydrogeologic characteristics.

knowledge about water resource issues and concerns, and develop the tools necessary to support decision-making regarding management recommendations to address the concerns.

RH2 Engineering, Inc., (RH2) was retained to prepare the water quantity assessment (Appendix A) and AMEC/GeoMatrix (AMEC) was retained to prepare the water quality assessment (Appendix B). In June 2010, The Watershed Company (TWC) was retained to prepare a habitat component (Appendix C) for the watershed plan.

During the water quantity assessment work, several sub-basin meetings were held to evaluate the level of effort warranted to further assess the water quantity sub-basins during Phase 4. Based on these meetings, the LCWPU concluded that the First Creek, Twenty-Five Mile Creek, and Antoine Creek sub-basins would not be included for detailed consideration of potential projects, and that the remaining basins would receive priority for planning.

AMEC compiled and summarized water quality monitoring data from 1975 to date, meeting one of the Phase 2 Water Quality assessment objectives. AMEC concluded that the data are not suitable for water quality trend analysis, and the LCWPU determined that long-term monitoring of Lake Chelan water quality constituents was the top priority objective for water quality monitoring. AMEC prepared a long-term monitoring plan (LTMP), which will be implemented during Phase 4.

During Phase 1, the LCWPU elected not to conduct habitat assessment based on substantial work completed by Chelan PUD for Federal Energy Regulatory Commission (FERC) relicensing (particularly the Lake Chelan Fishery Plan (LCFP)) and by Chelan County Natural Resources Department (CCNRD) in the Lake Chelan Sub-basin Plan (Berg, 2004). The LCWPU subsequently concluded that addressing ecological needs in the lake would support water quality issues in watershed planning. Proposed mitigation activities and new shoreline rules have prompted active involvement by the local community to jointly address these issues with Lake Chelan watershed planning. Therefore, the LCWPU broadened the scope of the planning effort and included the optional habitat assessment during Phase 3.

Phase 3, Watershed Plan Development: The watershed plan summarizes prior findings and develops recommendations for actions by local, state and federal agencies, tribes, private property owners, private organizations and individual citizens, including a recommended list of strategies and projects that would further the purpose of the plan (See RCW 90.82.040(2)(ii)). The LCWPU has agreed on the key findings and challenges facing watershed planning and recommended specific actions to address the key findings and challenges.

Phase 4, Implementation: Within one year of the adoption of the watershed plan, the LCWPU must complete a detailed implementation plan (DIP), which is a condition of receiving grants for the second and all subsequent years of the phase four watershed planning grant (See RCW 90.82.043). The LCWPU prioritizes the sequence of implementing actions based on its respective value, ease of implementation, and availability of funding.

1.1.2 Funding for WRIA 47 Watershed Plan Implementation

Assuming approval of a grant application for Phase 4 by the Washington State Department of Ecology, funding potentially available to WRIA 47 is shown in **Table 1**.

Table 1 - Potential Phase 4 Implementation Funding

Potential Phase 4 Implementation Funding	
Year	Available Funding (10 percent local match required)
1	$100,000
2	$100,000
3	$100,000
4	$50,000
5	$50,000
TOTAL	$400,000

Phase 4 implementation funding would be used to develop a detailed implementation plan, to support project management and continued activities of the LCWPU, and to serve as "seed money"' for receiving additional funding under various grant and loan programs to implement the recommendations of the watershed plan. During the project selection process, most funding entities favorably view an approved watershed plan and the inclusion of a proposed project in the detailed implementation plan.

1.1.3 Organization of WRIA 47 Watershed Planning

Lead Agency

Chelan County, the City of Chelan and the Lake Chelan Reclamation District initiated watershed planning in WRIA 47 and are recognized as "initiating governments" for watershed planning. These initiating governments established Chelan County as the "Lead Agency" for grant management, planning unit facilitation and consultant management purposes.

LCWPU Membership and Procedures

The following entities are members of the WRIA 47 LCWPU.

- Chelan County
- City of Chelan
- Lake Chelan Reclamation District
- Chelan County PUD #1
- Chelan-Douglas Health District
- Washington Department of Ecology (Ecology)
- Washington Department of Fish and Wildlife
- Washington Department of Health
- Washington Department of Natural Resources
- US Army Corps of Engineers
- US Forest Service
- Interested individuals

During Phase 1, the LCWPU established operating procedures to address how interested parties may become a member of the LCWPU, the loss of voting authority for members who do not actively participate in the process and the decision-making process. The LCWPU approved the planning unit charter in December 2007 (RH2/GeoMatrix, 2008).

The decision-making process includes the following definition of consensus for decision-making.

"I can live with the decision and accept it, even though it may not be exactly what I want."

In the event that full consensus is not reached, RCW 90.82.130(1) (a) states that:

Upon completing its proposed watershed plan, the LCWPU may approve the proposal by consensus of all of the members of the LCWPU or by consensus among the members of the LCWPU appointed to represent units of government and a majority vote of the nongovernmental members of the LCWPU.

1.2 OVERVIEW OF LAKE CHELAN WATERSHED (WRIA 47)

General Characteristics

The area occupied by the Lake Chelan Water Resource Inventory Area 47 (WRIA 47) comprises 1,044 square miles, of which 90 percent or 937 square miles includes Lake Chelan and its tributary sub-basins; the remaining 10 percent consists of sub-basins that drain to the Columbia River. One primary tributary, the Stehekin River, and one secondary tributary, Railroad Creek, discharge 85 percent of WRIA 47 runoff into Lake Chelan. The management area consists of ten sub-basins shown on **Figure 1**. Approximately 1.8 percent (19 square miles) of WRIA 47 lies within Okanogan County.

Topography and Vegetation

WRIA 47 has physical and vegetation characteristics similar to other east-slope Cascade watersheds. The watershed includes glaciers and rugged mountains at the highest elevations, dense fir and open ponderosa pine forests, wide expanses of shrub-steppe, and narrow riparian zones in lower elevations. Elevations in WRIA 47 range from 700 feet above mean seal level (MSL) at the Columbia River to 9,511 feet MSL at Bonanza Peak. Landforms consist of the classic U-shaped glacially-carved valleys of Lake Chelan, the Stehekin River and smaller tributaries in the higher elevation sub-basins, which are surrounded by high ridges and steep cliffs. Lower elevation sub-basins are narrower incised valleys that are tributaries to Lake Chelan and the Columbia River, bounded by rolling hills near the lake's terminus at the City of Chelan, and gravel terraces along the Columbia River.

Lake Chelan and its immediate surroundings are the result of the complex interaction between two glacial masses. The lake was formed approximately 15,000 to 18,000 years ago during the Vashon/Wisconsin glacial period. During this time, the Chelan Glacier moved down the valley from the Cascade Crest, and the Okanogan-Columbia Valley lobe of the Cordilleran ice sheet extended upward from the south. The two glaciers approached each other and nearly met at Wapato Point and a constriction known as "The Narrows" (a shallow ledge 135 feet below the surface of the lake at its narrowest part). The lake consists of two basins: the Lucerne basin, which is deep and fjord-like and extends north from The Narrows for approximately 40 miles to the Stehekin River; and the Wapato basin, which is relatively wide and shallow in comparison (maximum depth of 400 feet) and extends for approximately 15 miles south of The Narrows (Whetten, 1967) to the lake outlet at the head of the Chelan River.

Geology

Bedrock comprises much of the exposed surficial geologic units on the steeper slopes above terraces and hills of the lower basin, and forms the slopes and ridges of the upper basin above 1,600 feet in WRIA 47. Glacial episodes deposited relatively broad layers of fine to coarse-grained sediment in the valley floors and partially on the valley sidewalls or in patches on ridges. Lakeshore, river and landslide deposits are found primarily along river and creek bottoms and at the base of slopes. The glacial and post-glacial deposits contain most of the available groundwater in WRIA 47, and nearly all developed and irrigated lands are underlain by unconsolidated geologic units. The unconsolidated deposits are found primarily as discontinuous layers of sediment in the Wapato Main Stem and Manson Lakes Sub-basins, as terrace and flood deposits in the Antoine Creek and Howard Flats Sub-basins, and locally as alluvial fill in the valley bottoms of other sub-basins.

Hydrology

Precipitation that is not lost to evapotranspiration runs off steep slopes into stream channels, minor tributaries and primary tributaries of the Stehekin River and Railroad Creek, where they ultimately discharge out of Lake Chelan into the Chelan River and finally into the Columbia River. Smaller tributaries include 25-Mile, First, Fish, Prince, Gold, and Safety Harbor Creeks (**Figure 1**). Minor amounts (less than 5 percent of total WRIA 47 discharge) of stream flow discharges from sub-basins adjacent to the Columbia River. **Table 2** summarizes tributary stream flow data for the year 2000.

Table 2 - Summary of Stream Flow Data in 2000

Stream	Maximum Peak Flow (cfs)	Date	Base Flow (cfs)	Date (2000)
Stehekin River	6,010	May 22	1,130	Aug 1 – Sept 28
Railroad Creek	1,284	June 15	153	Aug 1 – Sept 28
Prince Creek	531	June 18	26.1	July 1 – Sept 28
Fish Creek	526	June 21	24.6	July 1 – Sept 28
25-mile Creek	145	May 23	8.5	July 1 – Sept 28
Safety Harbor Creek	141	June 8	5.3	July 1 – Sept 28
First Creek	97.8	April 14	7.6	May 15 – Sept 28
Grade Creek	35.8	April 22	2.6	July 1 – Sept 28
Gold Creek	11.1	April 20	0.7	June 1 – Sept 28
Mitchell Creek	6.5	April 31	1.8	May 15 – Sept 28

Figure 2 illustrates stream flow data for the Stehekin and Chelan Rivers; average annual flows have not changed significantly over the period of gauging, from the early 1900s to date. The Stehekin River flow is typically 65 to 80 percent of Chelan River flow.

Primary and tributary streams to Lake Chelan experience peak runoff during the spring melt in May to July, and low flows during September through February (**Figure 3 and Figure 4**). Water in Lake Chelan is generally stored during the runoff period and released during the low flow season to generate hydroelectric power, resulting in a flattened hydrograph compared to natural flows (**Figure 5**).

Average annual inflow to Lake Chelan is estimated to be approximately 1.6 million acre-feet (af), equivalent to a constant flow of approximately 2,200 cubic feet per second (cfs). The Stehekin River accounts for 65 percent of the total inflow to the lake, Railroad Creek contributes 10 percent and approximately 50 other smaller tributaries contribute another 25 percent of the surface inflow (FERC, 2001). Precipitation that falls directly on the lake contributes 4.4 percent of the total inflow to the lake, or approximately 70,000 af per year.

Groundwater

Groundwater in WRIA 47 is replenished from precipitation falling in the basin and infiltrating into porous surficial deposits. The broader and hilly terrain of the lower watershed sub-basins promotes groundwater recharge. In contrast, steep, thinly covered bedrock areas promote runoff and little recharge into bedrock fractures. Groundwater is recharged artificially via seepage from irrigation drains, via return flow infiltrating from irrigated lands, and via seepage from Wapato, Roses and Dry Lakes in the Manson Lakes Sub-basin. Groundwater elevations and yield to wells in these areas are expected to be artificially high relative to non-irrigation conditions.

Population

The 2000 Washington State Census data determined a population of 11,706 within WRIA 47 (excluding the Okanogan County portion of the watershed). The Census forecasted a population of 13,104 for 2008 and 15,650 by 2025. The highest population density in WRIA 47 exists along the lake shoreline. Most residents work within the watershed and live within the Wapato Main Stem and Manson Lakes Sub-basins.

Land Use

Most of the watershed is under federal management, primarily by the US Forest Service and National Park Service; approximately 87 percent of the Lake Chelan watershed is in federal, state, and local-government ownership. The remaining 13 percent is in private ownership. Hillsides above the lakeshore and lower elevation uplands are irrigated for orchard, vineyard and pasture. Lake Chelan is managed for multiple uses including power, recreation, irrigation, potable water supply, historic and cultural preservation, fisheries, wildlife and habitat.

Water Rights

Ecology's water rights records indicate that more than 800 active certificated water rights are authorized in WRIA 47, consisting of 700 surface water rights and 100 groundwater rights. There are 133 surface water permits and 30 groundwater permits. The database identifies 530 surface water claims and 148 groundwater claims. Approximately 50,000 af of water rights and claims are filed with Ecology for water in

Lake Chelan sub-basins within WRIA 47, and more than 350,000 af of water rights and claims are filed for water in Columbia River sub-basins within WRIA 47.

In 1992, Chelan PUD and Ecology prepared an agreement in which the Chelan PUD water right Certificate 319 authorizes Chelan PUD to withdraw 4000 cfs from the Chelan River for hydroelectric power generation with an unspecified annual use. Permit 548 established a reservation of 33,000 af per year for above-dam diversion for irrigation and domestic use in the watershed. The agreement creates a 20,000 af reservation of new water right from unused portion of Certificate 319 for use only within Chelan WRIA 47. The potential future uses for the 20,000 af reservation have not been quantified or prioritized, but are likely subject to the first-in-time priority of pending water right applications.

Water Use

Approximately 89 percent of households receive water from WRIA 47 surface water sources provided by 12 Group A Community systems, with 11 percent from groundwater (7 percent from exempt wells, 4 percent from 63 Group B systems). Approximately 2,500 af of water is used each year for residential consumption. Much of the wastewater from WRIA 47 is collected, treated, and discharged to the Columbia River.

Approximately 16,000 af of water is used for irrigation in the Wapato Main Stem sub-basin, and 5,000 af of water is used for irrigation in Columbia River sub-basins, primarily for orchard crops.

Approximately 350 af of water is used in the Wapato Main Stem sub-basin for commercial and industrial use.

Lake Chelan Project

Lake Chelan is a regulated reservoir under FERC license that was initially authorized in 1926 and re-authorized on November 6, 2006. The Lake Chelan Hydroelectric Project FERC Project No. 637 consists of Lake Chelan, a 1,486-foot-deep, 55-mile-long natural glacial lake that was raised 21 feet by the construction of the 40-foot-high, 490-foot-long concrete gravity dam in 1926. Lake Chelan is a 32,560-acre reservoir at normal maximum water surface elevation of 1,100 feet MSL, with a gross storage capacity of 15.8 million af and a useable storage of 677,400 af.

Chelan PUD establishes target elevations to be achieved between May 1 and October 1, based on seasonal runoff and operational objectives including:

- maintaining minimum instream flows in the Chelan River;
- reducing high flows in the Chelan River; and
- providing usable lake levels for recreation (between 1,090 and 1,098).

The minimum flow varies depending on the time of year and whether it is a dry, normal, or wet water year.

Approximately 2,000 acres of project land lie within the Lake Chelan Project boundary. About 1,300 acres of the Project lands are inundated and project facilities occupy the other 700 acres. The Project lands are owned by the US Forest Service, National Park Service, several state agencies, Chelan PUD, and private property owners. Approximately 465.5 acres are inundated federal lands.

2.0 WRIA 47 WATERSHED PLANNING ACTIVITIES

2.1 PHASE I WATERSHED PLANNING INITIATION

During Phase 1, the LCWPU developed the following vision, mission, goals and objectives for watershed planning in WRIA 47.

Vision

Recognize, inform, educate, monitor, understand and protect the unique water resource that is Lake Chelan; the ecological processes and pathways essential to maintaining this high quality water body; and the ways in which we can live on this lakeshore, enjoy this unique treasure and protect it for generations to come.

Mission

To develop an understanding of water and related aquatic and land resources by building trust and positive working relationships among diverse interests in the watershed to achieve a sustainable balance of economic, social and environmental values.

Goal

To implement a management plan for water use and protection that sustains the environmental, educational, economic and recreational values associated with a healthy lakeside community and watershed.

Objectives

- Assess water supply, use and projected needs.
- Develop and implement a comprehensive, long-term monitoring program of key parameters that will ensure water quality sustainability throughout the Lake Chelan Watershed (WRIA 47).
- Address water bodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.
- Inform and educate local communities and visiting populations about water quality protection.
- Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources.

The initiating governments view watershed planning as a complement to other water resource management efforts in WRIA 47, including implementing regulatory actions as part of re-licensing the Chelan Dam and work done by the LCWQC.

Anticipating Phase 2 of watershed planning, the LCWPU elected to conduct the required water quantity assessment and the optional water quality assessment. The LCWPU elected not to review or modify instream flows established under FERC process. The LCWPU elected to conduct a summary habitat assessment incorporating work completed by the USFS, WDFW, and Chelan PUD. Habitat recommendations are summarized in **Section 3**.

2.2 PHASE II WATER QUANTITY ASSESSMENT

An assessment of water quantity is a required component of watershed planning under RCW Chapter 90.82. The water quantity assessment of a management area must include:

- An estimate of the amount of water present, taking into account seasonal variations;
- An estimate of the amount of water currently being used;
- An estimate of the amount of water allocated by rights to water including instream flow rules;
- An estimate of future water demands;
- An estimate of the amount of water available for further appropriation; and
- The identification of areas where groundwater is known to recharge and where it contributes to surface water bodies.

Methods

Several detailed water balance studies have been prepared for the Lake Chelan basin since the 1970s, which were reviewed and updated as part of the Phase 2 Water Quantity Assessment (RH2, 2009). The updated water balance used existing information to estimate input (precipitation and imported water from outside the basin), water loss (evapotranspiration, recharge to groundwater and consumptive loss from beneficial uses). Although primary tributaries and lake level data are available to the 1920s, continuous stream flow data for minor streams in WRIA 47 are sporadic and limited in use for estimating sub-basin runoff. The difference between estimated input and output variables was attributed to runoff. The water balance was estimated for natural and developed conditions and average, dry/warm and wet/cool years.

Groundwater resources, including potential aquifers and volumes, water bearing regions, recharge areas and gaining/losing stream reaches were assessed by examining well logs, topographic and geologic information.

Water rights data obtained from Ecology, including water rights permits, certificates and claims were mapped in Geographic Information Systems (GIS) to display the distribution of sources and place of use.

The amount of water available for future appropriation was estimated by subtracting estimated runoff and available groundwater quantities from water allocated through existing water rights.

Findings

The Water Quantity Assessment report (**Appendix A**) presented the following findings and recommendations that relate to water storage, as detailed below.

- The water balance estimates indicate that most of the physically available water (precipitation runoff, shallow groundwater recharge, imported water) entering WRIA 47 is discharged through the Lake Chelan reservoir and used for power generation.
- The lack of stream flow and groundwater data is responsible for large variation in water balance estimates for the sub-basins. Evaluation of the shift in water resource use in these sub-basins will require additional data and analysis to quantify.
- Irrigation water use is very efficient and the incremental improvements in irrigation efficiency are unlikely to significantly increase water availability in the basin.
- Commercial and industrial water use are minor components of the water balance; increased efficiency or reuse of commercial and industrial water are unlikely to significantly increase water availability in the basin.
- Much of the domestic water used in WRIA 47 either returns as groundwater storage and base flow seepage into Lake Chelan, or is exported from the basin to the Columbia River as treated wastewater; domestic consumption is a minor component of water balance.
- Converting the use of water from irrigation use to domestic use could substantially affect groundwater recharge and base flow in the sub-basins, since the consumptive loss of domestic water is low relative to total water present.
- Compilation of current use and estimates of future use are based on limited documentation of actual beneficial uses and return flows.

Recommended Actions from Phase 2 Water Quality Assessment

- Improve the documentation of beneficial water use, inchoate rights, municipal water supply, commercial/industrial use, irrigation water use and irrigation return flow to update water balance estimates, monitor the effects of changes in water use, and improve estimates of future water availability.
- Initiate monitoring of surface water and groundwater bodies where changing land and water use would affect water quality and habitat conditions, and to support long-term monitoring plan (LTMP) objectives.
- Use improved water balance estimates to support implementation of water quality studies and water quality management.

2.3 PHASE II WATER QUALITY ASSESSMENT

Methods

Phase 2 Water Quality activities summarized water quality data from previous assessments, including identifying all WRIA 47 water bodies with potentially impaired water quality, and identifying the parameters currently on the Clean Water Act 303(d) list. The information collected in all of the available water quality studies conducted in WRIA 47 since 1972 were reviewed to identify monitored parameters and to assess whether existing data sufficiently indicated detectable trends in water quality. The findings of the assessment and the compilation of information from the available water quality studies were summarized in two separate technical memos prepared in 2009: Assessment of Water Quality Issues within WRIA 47 (AMEC, 2009a); and Review and Summary of Existing Water Quality Studies within WRIA 47 (AMEC, 2009b). These two documents met the watershed planning objectives for a Phase 2 Water Quality Assessment (**Appendix B**).

Findings

Water quality assessment of phosphorous in Lake Chelan was conducted between 1986 and 1989 with Ecology oversight, and a Total Maximum Daily Load (TMDL) for phosphorous in Lake Chelan was approved by Ecology and EPA in 1993. The Lake Chelan DDT/PCB TMDL to address the DDT and PCB contamination contained in the tissues of fish in the Lake Chelan Watershed was initiated in 2003 and completed in 2006. The TMDL identified potential actions designed to prevent DDT and PCB inputs to Lake Chelan and Roses Lake. Monitoring fish tissue concentrations will be the primary strategy to track progress of the TMDL implementation approach. TMDL targets will be achieved only when fish tissue targets are met. Ecology proposes to evaluate the need for fish tissue data collection and evaluation every five years to assess progress toward meeting TMDL targets.

Ecology provided the following recommendations following completion of the DDT and PCB in Fish TMDL (Ecology, 2005, 2006):

- The Washington State Department of Health should evaluate the need for fish consumption advisories for Lake Chelan and Roses Lake. If advisories are recommended, public notices should be posted at all public boat launches to the lakes. The public should be aware of potential problems from consuming fish in excess of recommended levels.
- DDT levels should be the primary focus for water quality managers in the Lake Chelan basin. PCB levels should be followed, but management options are more limited.
- Monitoring pollutant levels in lake trout tissue allows an evaluation of the worst-case scenario for total DDT and PCBs in fish tissue. Until total DDT and PCBs in fish tissue are within acceptable levels, tissue concentrations should continue to be monitored. Because lake sediments act as a large source pool for pollutants, evaluating tissue concentrations will be required far into the future.

- Natural attenuation should be considered the best management strategy for total DDT in Lake Chelan and Roses Lake sediments. Active removal of total-DDT-laden sediments from Lake Chelan is not an option, considering size and depth, disturbance to fish and invertebrate communities, and damage to habitat. Natural attenuation is also the least costly of management options.
- Pollutant input to the Wapato basin of Lake Chelan and to Roses Lake should be controlled to the extent possible, to help in recovery and to avoid exacerbating conditions. Investigations of sub-basins would be required to identify any specific sources for load reductions.
- Load reductions could occur just prior to discharge through developed wetland treatment, if and where feasible.
- An evaluation of total DDT concentrations in the water column from the Wapato basin should be conducted to better quantify spatial and temporal variations.
- An evaluation of the importance of total DDT loading from groundwater to the Wapato basin should be conducted.

Actions based on TMDL recommendations have included the following:

- Washington State Department of Health issued a fish consumption advisory for lake trout in Lake Chelan in 2004. Ecology has conducted periodic fish tissue sampling and evaluation.
- Management activities are being targeted primarily for DDT. However, PCB actions are being implemented, such as education, PCB transformer recycling, cleanup of old PCB sites, pesticide pickup days, etc.
- The LCWQC completed a Department of Ecology Centennial grant to continue monitoring sediment, soil, surface water, groundwater, and fish uptake mechanisms and to conduct education and outreach activities for the community, growers, schools, and media.
- The LCWQC and participating entities have worked with growers and irrigation districts to encourage and implement practices that utilize water efficiently, which will improve crops, reduce surface runoff and deep percolation and in turn reduce DDT transport to ground and surface waters.

Water quality concerns within WRIA 47 include elevated concentrations of organochlorine pesticides, PCBs, and dioxins/furans within fish tissues, and elevated water quality constituents including phosphorous, pH, dissolved oxygen, and invasive exotic plants. Water quality monitoring data for WRIA 47 were obtained to meet study-specific objectives and contain few consistently measured parameters; this limits the ability to evaluate long-term trends in water quality in WRIA 47. This lack of adequate monitoring data led to LCWPU recommendation to develop and implement a long-term monitoring plan (LTMP). The LCWPU recommended developing a water quality model to evaluate water clarity/eutrophication, and a bioaccumulation food-web model to model toxics transfer between sediment, water, and the aquatic food chain.

Long-Term Monitoring Plan

The WRIA 47 Water Quality Subcommittee identified water quality trend analysis for Lake Chelan as the top priority planning objective and recommended development of a Long-Term Monitoring Plan (LTMP) for Lake Chelan. The LTMP goals included identifying data gaps, collecting data on a consistent basis to develop water quality trends, and providing a proactive or adaptable plan for WRIA 47. The LTMP objectives include the following:

- Develop a monitoring design supported by water quality models that can be used to evaluate trends in water quality parameters.
- Evaluate concerns about potential future changes in water clarity and lake eutrophication.
- Develop a monitoring approach for constituents that have completed TMDLs to allow a determination of the effectiveness of post-TMDL remedies (phosphorous, DDT analogs, PCBs).
- Develop a monitoring design for 303(d)-listed constituents in Lake Chelan that have not yet been addressed through the TMDL process (alpha-BHC, chlordane, dieldrin, dioxin/furans).
- Recommend data quality objectives and analytical methods to ensure greater consistency and comparability of data in the future.
- Develop a monitoring program that can be used to evaluate best management practices (BMPs) that may be implemented to address water quality concerns.

The proposed LTMP study area includes the southern 6 miles of the Lucerne Basin and all of the Wapato Basin, regions that have experienced the greatest development and where most of the water quality problems have been identified. The proposed study area includes four lake reaches within the Wapato Basin and six lake reaches in the lower Lucerne Basin, and the mouths of four tributaries to Lake Chelan.

AMEC prepared the LTMP (AMEC, 2009c) and associated Quality Assurance Project Plan (QAPP) for water quality modeling (AMEC, 2009d). The LTMP summarizes ideas and recommendations proposed by the WRIA 47 Water Quality Subcommittee members for the development of the LTMP and provides an initial framework for the plan that focuses on the calibration and application of two models 1) QUAL-W2, a water quality model to support evaluation of water quality conditions including water clarity, and eutrophication; and 2) the Lake Chelan food web bioaccumulation model. The QAPP for the QUAL-W2 model will guide the collection, management, and interpretation of data used in the model. Due to funding cuts, a QAPP for the food web model was put on hold, pending future funding.

Use and application of water quality and food web models as part of a monitoring program:

- Support the understanding of the sources of constituents of concern and the transfer among different environmental media;
- Support prediction of how constituents of concern will change based on different loading scenarios, application of best management practices, or natural attenuation; and
- Support the evaluation of the relative importance of different monitored parameters to allow adjustments to be made to the monitoring design.

QUAL-W2 model

One year of data is needed to calibrate the QUAL-W2 model, which would then be used to predict water quality changes, evaluate the effectiveness of BMPs, and support evaluation of monitoring needs and the effectiveness of the monitoring design for Lake Chelan.

Data needs for calibrating and applying the model require information for a water balance (inflows, surface water elevation, and outflows), inflow constituent concentrations, and longitudinal and vertical profiles specifying initial conditions for each cell (lake reach). Water quality parameters will be collected at defined monitoring stations over a sufficient period of time to characterize seasonal and episodic (e.g., storm events) water quality changes in Lake Chelan.

Bioaccumulation Food Web Model

The Lake Chelan food web model, would examine the distribution of DDT, DDE, and DDD within Lake Chelan sediment, water, and aquatic biota, and predict the accumulation of DDT in aquatic species from the water and diet. Monitoring data incorporated into the model would include water column concentrations of dissolved and particulate organic carbon, tissue concentrations of toxics in key prey species, and concentrations of toxics in sediment, water, and benthic biota. Data needs for applying the model also include information for a water balance (inflows, surface water and groundwater elevation, and outflows), inflow constituent concentrations, and longitudinal and vertical profiles.

The food web model would:

- Provide a mechanism for understanding of the sources of constituents of concern and the transfer among different environmental media;
- Provide a way to predict how constituents of concern will change based on different loading scenarios, application of best management practices, or natural attenuation;
- Provide a way to evaluate the relative importance of different monitored parameters to allow adjustments to be made to the monitoring design.

Recommended Actions from Phase 2 Water Quality Assessment

- Initiate water quality modeling (QUAL-2K) and bioaccumulation food web modeling of toxic compounds in fish tissue to support the characterization and monitoring objectives of the LTMP.
- Calibrate the QUAL-2K water quality model with one year of data
- Prepare a Quality Assurance Project Plan (QAPP) for the Food Web model.
- Initiate the bioaccumulation Food Web Model.
- Implement the LTMP based on the findings of the models.

2.4 HABITAT ASSESSMENT

The optional habitat component of Phase 3 watershed planning "must rely on existing laws, rules, or ordinances created for the purpose of protecting, restoring, or enhancing fish habitat, including the Shoreline Management Act, RCW Chapter 90.58, the Growth Management Act, RCW Chapter 36.70A, and the Forest Practices Act, RCW Chapter 76.09" (RCW 90.82.100). Strategies developed under this component of the plan were intended to address listed salmon and other fish species in WRIA 47.

Methods

The habitat assessment addressed both aquatic habitat and fish species. While fishery management often involves habitat restoration and/or other habitat considerations, it may also include methods and processes distinct from habitat management. However, both habitat and non-habitat management components are vital to fish management in WRIA 47 and are the subjects of public interest and past restoration efforts.

Substantial work regarding aquatic habitat, watershed processes, and aquatic species composition and interactions has been previously conducted in WRIA 47. This work, including watershed assessments, planning documents, and management recommendations, is presented in the Phase 3 Habitat Component (TWC, 2011; see **Appendix C**). No new habitat studies were performed specifically for the habitat component. Phase 3 also draws upon previous studies and documents, including the Lake Chelan Fishery Plan (LCFP; Chelan PUD, 2007), the Lake Chelan Sub-basin Plan (Laura Berg Consulting, 2004), and WRIA 47 Phase 2 Water Quality and Water Quantity Assessments, to formulate goals, recommendations, and strategies.

Findings

Factors impacting fish populations in the watershed include habitat degradation and loss; land development, conversion, and management; agricultural practices; fish-passage barriers; dam operations; flooding; species introductions; interspecific breeding; competition for resources; disease; harvest; and hatchery and stocking operations. Impacts and their effects on aquatic habitat in the watershed are described in **Table 3**.

Table 3 - Major Impacts with Associated Ecological Functions in Lake Chelan WRIA 47

Impact Source	Impact Action(s)	Function(s) Affected
Fire suppression	Loss of riparian vegetation, flashy stream flows, erosion and sedimentation	Water quality, hydrology, habitat
Land conversion	Loss of shrub-scrub, wetland, and riparian; pesticide and fertilizer use; irrigation; invasive species propagation	Water quality, habitat
Dam operations	Raised/fluctuating lake levels, entrainment, fish passage barriers	Hydrology, habitat, lake ecology
Docks and piers	Shading, structure in water	Habitat
Bulkheads and armoring	Loss of lakeshore vegetation, wetland loss, wave action alteration, erosion, alteration in recruitment of woody debris and sand/gravel	Hydrology, habitat
Non-fish-passable culverts	Fish passage barriers	Habitat, lake and tributary ecology
Other terrestrial development	Loss of native vegetation, ornamental species propagation, septic systems	Water quality, habitat
Agriculture and grazing	Loss of scrub-shrub, wetland, and riparian; pesticide and fertilizer use; sedimentation and erosion	Water quality, habitat
Fish introduction	Disruption of the food web, complex habitat interactions, introduction of disease.	Lake and tributary ecology

The fish community in Lake Chelan and its tributaries is an assemblage of native and non-native species. Main impacts and interactions among species are described in the Lower Lake Chelan In-Lieu Fee (ILF) Prospectus (TWC, 2010). Competitive pressures on native and popular non-native species are compounded by impacted habitat conditions summarized in **Table 3** above. The main impacts and interactions among species are summarized in **Table 4**.

Table 4. Major fish species interactions, impacts and production in Lake Chelan WRIA 47

Species	Impacts and Interactions	Function/Use	Reproduction/Support
Bull trout (native)	Decline due to over-harvest, interbreeding, disease, loss of spawning habitat; reintroduction hindered by competition from Kokanee and trout	Historic occurrence, threatened species	Not observed in Lake Chelan or tributaries since early 1950s
Chinook salmon (introduced)	Forage competition from mysids and lake trout, hatchery conditions, flooding, over-harvest, improved angling methods	Strongly supported recreational fishery until early 1990s, community desire to rebuild fishery	Reproduces naturally in low numbers, stocked, declining population
Kokanee (land-locked Sockeye salmon-introduced)	Forage competition from mysids, predation by Chinook salmon, flooding, interbreeding	Strongly supported recreational fishery	Reproduces naturally, expanding population in Stehekin River, stocked previously, 2007 spawners found sufficient to support population
Westslope cutthroat trout (native)	Gradient and velocity barriers, competition from non-natives, over-harvest, mining contaminants, logging impacts, hatchery operations, interbreeding	Strongly supported recreational fishery	Reproduces naturally in tributaries, stocked with hatchery fish, hybridizes with rainbow trout
Lake trout (introduced)	Compete with and prey on native and introduced fish, exceed DDT health standards in adipose	Popular trophy fish	Reproduce naturally in Lake Chelan, stocked previously
Rainbow trout (introduced)	Outcompete and hybridize with native westslope cutthroat trout	Strongly supported recreational fishery (triploids)	Stocked since early 1990s, hybridize with cutthroat trout, no reproductive fish stocked since 2005, triploids stocked
Smallmouth bass (introduced)	Danger of competition with or predation of native fish	Recreational fishery	Introduced illegally in 1990, reproducing in and presently limited to Wapato sub-basin

Species	Impacts and Interactions	Function/Use	Reproduction/Support
Eastern brook trout (introduced)	Compete with native fish; spread disease	Recreational fishery	Established in Stehekin River and Twenty-five Mile Creek from historic stocking
Burbot (native)	Competition for mysids, limited salmonid predation	Minor recreational fishery	Limited understanding of abundance and habitat

Species statuses and interactions were evaluated in a fish predator behavior and population dynamics study by Schoen and Beauchamp (2010) as part of LCFP implementation. Present and historic habitat issues and conditions in WRIA 47 are described in the Phase 3 Habitat Component (Appendix C). Anthropogenic impacts on each habitat type affect the aquatic habitat in WRIA 47 by disturbing or modifying natural habitat functions, which consequently alter water quality and/or quantity and availability and quality of habitat.

Table 5 lists knowledge gaps and management limitations that pertain to the main predators and game fish in Lake Chelan. These gaps and limitations must be addressed before implementing species-based recommendations.

Table 5 - Main knowledge gaps and management limitations for major species in Lake Chelan

Species	Knowledge Gaps
Westslope Cutthroat trout	Small population makes it difficult to determine predation effects on recovery
	Data suggest species uses the lake in very small numbers (Chelan PUD 2001a, 2001b)
Kokanee	Desired population size not defined
	Recruitment and abundance in Lake Chelan unknown
Chinook salmon	Lacking extensive diet and growth rate information
	Lacking information on natural reproduction
Bull trout	Undetermined whether natural populations exist in the watershed
	Unknown whether existing habitat can support species
	Potential interactions with other species largely unknown
Lake trout	Lake trout reproductive rate knowledge gap makes predicting future predation impacts on kokanee difficult (Schoen and Beauchamps, 2010)
	No plan presently to control population growth
	Lake trout recruitment rate from natural reproduction unknown
Burbot	Limited understanding of abundance and habitat

Recommended Actions from Habitat Assessment

Previous studies and the information contained in the Phase 3 Habitat Component (**Appendix C**) and in the LCFP highlight the issues and objectives regarding fish and aquatic habitat restoration and management in the Lake Chelan watershed. The LCFP presents the potentially conflicting objectives of restoring and managing Lake Chelan for native species while also supporting the management of recreational sport fisheries. The following recommendations are intended to fill knowledge gaps, work toward resolution of competing management objectives, and lead to effective restoration implementation in the watershed.

1. Evaluate and understand the role of fisheries and fishing activities in the local economy and consider broad-based efforts to address competing fisheries management issues.

2. Support existing and encourage new monitoring efforts, as outlined in the LCFP, to gain a better understanding of habitat utilization and interactions among the fish species present in Lake Chelan.

3. Utilize new and developing science to further understanding of predator-prey relationships and strategies, life-stage habitat use, and species reproduction in the lake and its tributaries.

4. Support the exploration and study of potential impacts of the management approaches offered in the LCFP.

5. Support habitat restoration efforts that improve identified limiting factors for both fish and wildlife.

6. Encourage participation in LCWPU activities and development of a detailed implementation plan to develop fish and wildlife priority actions for implementation of the watershed plan.

2.5. OTHER WRIA 47 PLANNING ACTIVITIES

Other planning activities not conducted under WRIA 47 watershed Planning have similar water quality, water quantity, and habitat management objectives and activities that overlap with those of WRIA 47 watershed planning. These activities include the Chelan County Shoreline Master Program (SMP) update; Chelan County in-lieu fee program development; Chelan PUD FERC license activities under the Lake Chelan Settlement Agreement; and development of the Northwest Power and Conservation Council Lake Chelan Sub-basin Plan.

2.5.1 Shoreline Master Program Update

Shoreline Master Programs (SMP) are a combination of rules and comprehensive planning that are developed by local governments to guide the development of stream and lake shorelines in accordance with the 1971 State Shoreline Management Act (RCW 90.58). The local SMP is essentially a shoreline-specific combined comprehensive plan, zoning ordinance, and development permit system. The Act emphasizes accommodation of appropriate uses that require a shoreline location, protection of shoreline environmental resources and protection of the public's right to access and use the shorelines (RCW 90.58.020).

Chelan County adopted the SMP in 1975 and is currently updating the SMP, which was submitted for public review draft form in August 2010. A Shoreline Restoration Plan will implement the updated SMP to address impaired ecological functions, provide environmental protection for shorelines, preserve and enhance public access, and encourage appropriate development that supports water-oriented uses.

2.5.2 FERC License and Implementation of Lake Chelan Comprehensive Plan

FERC relicensing led to the Lake Chelan Comprehensive Plan prepared by Chelan PUD in 2003 to implement the Lake Chelan Settlement Agreement. Chelan PUD established several plans to manage erosion, fisheries, and wildlife habitat in the Lake Chelan Project area. Objectives of these plans overlap WRIA 47 water quality, quantity, and habitat objectives. Chelan PUD has initiated and funded these planning activities with various levels of participation by federal, state, county and local agencies.

Erosion Control Plan

The National Park Service and the US Forest Service have implemented shoreline protection and restoration activities under the Erosion Control Plan. A large woody debris (LWD) program was initiated to support implementation of the erosion control and fishery plans. Future activities and management of the LWD program is under review and discussion by residents and government agencies.

Fishery Management Plan

WDFW has primary responsibility for fishery management in Lake Chelan. Fishery management plan objectives include restoring and enhancing habitat for native species, maintaining water quality and quantity, and coordinating plans and actions of other WRIA 47 stakeholders in developing fishery management measures. A significant monitoring objective included developing a food web model to support the development and management of the fishery management plan.

Wildlife Habitat Plan

The Wildlife Habitat Plan seeks to enhance wildlife habitat bordering Lake Chelan to restore, maintain, or improve ecological quality and diversity. Chelan PUD has funded and will continue to fund restoration projects along uplands, shorelines, and riparian zones.

2.5.3 Lower Lake Chelan In-Lieu Fee Mitigation Program

Chelan County, in conjunction with federal, state, and local agencies and tribes, is developing an In-Lieu Fee (ILF) mitigation program to offer an alternative means of mitigating for unavoidable aquatic impacts when on-site, in-kind mitigation is not practicable. The ILF is described in the Lower Lake Chelan ILF Prospectus and Compensation Planning Framework (The Watershed Company, 2010). Chelan County submitted the ILF Prospectus to the Army Corps of Engineers and Ecology, and is meeting with other state and local agencies for review and approval. The program would pool fees from the shoreline permitting process into an ILF program account. The fees would be used to develop mitigation projects that would have much greater benefit to Lake Chelan shoreline conditions than piecemeal mitigation projects under the current LWD program. The ILF project would have long-term maintenance and monitoring support to ensure the ongoing effectiveness of mitigation projects.

2.5.4 Lake Chelan Sub-basin Plan

The Lake Chelan Sub-basin Plan (Laura Berg Consulting, 2004, for NW Power and Conservation Council) established the goal to "restore conditions to a more natural state" by employing "ecosystem-based perspectives that consider multiple species, their life histories, and their inter-relationships." The Sub-basin Plan includes a detailed inventory, and concludes with a number of habitat or biological objectives for key species and key habitats in the basin. Aquatic conservation strategies in the plan focus on fish populations and habitats. Funding sources for recommended actions are not specified.

3.0 SUMMARY OF RECOMMENDED ACTIONS

Preliminary objectives for watershed planning in WRIA 47 were developed by the LCWPU during Phase 1 in 2008. WRIA 47 water quantity and quality conditions and challenges to meet the LCWPU objectives were identified during Phase 2 Watershed Planning, which included water quantity assessment and compilation of water quality conditions. Recommendations from the Phase 2 assessments were developed and carried forward into the Phase 3 watershed planning effort. A summary habitat assessment, compiled during Phase 3, identified watershed planning-related objectives and conditions to protect and enhance fish habitat in WRIA 47, and recommendations from habitat assessment activities are included in the Phase 3 watershed planning effort. The LCWPU reviewed and refined recommendations to meet the objectives developed in Phase 2 and 3, and the Phase 3 watershed planning recommendations are summarized in this section.

Specific watershed planning activities will be evaluated and prioritized as part of the Phase 4 detailed implementation plan following adoption of the watershed plan. Watershed planning objectives in WRIA 47 overlap objectives of other water, land and habitat management activities. The LCWPU members and stakeholders will improve the effectiveness of implementing watershed planning activities as they are coordinated with parallel activities in WRIA 47.

3.1 Water Quantity Summary

Objectives

- Improve estimates of beneficial uses to support water quality assessment and habitat enhancement and protection.

Findings and Challenges:

- Estimates of total water supply availability are imprecise based on assumptions of beneficial use and inchoate water rights.
- Water is available for appropriation subject to the terms of the 1992 Agreement between Chelan PUD and Ecology, and the 2006 renewal of the FERC license for Lake Chelan Dam.
- Irrigation use and return flow are not quantified and have the greatest effect on current and future water balance.
- Changes in land use and population in the Wapato, Manson and lower Lucerne sub-basins will affect local water use, water quality, and habitat conditions. Limited and sporadic water data are needed to predict and manage these changes.

Recommended Actions for Water Quantity:

- Improve the documentation of beneficial water use, inchoate rights, pending applications for new water rights, existing municipal water supply, irrigation water use, and irrigation return flow to update water balance estimates and monitor the effects of changes in water use to improve estimates of future water availability in WRIA 47.

- Initiate surface water and groundwater monitoring in the Wapato, Manson and lower Lucerne sub-basins to provide data to support water quality and habitat monitoring and improvement plans in WRIA 47.
- Use improved water balance estimates to support implementation of water quality studies and water quality management.
- Promote joint comprehensive analysis and prioritization of future municipal/domestic use by large and small Group A systems, Group B systems, future irrigation use, and future commercial/industrial use.
- Evaluate regional growth patterns, regional demands, inchoate water rights and water system connections for future/expanded service areas.
- Evaluate potential future irrigation demands and transfers of water rights following conversion of agricultural land prior to transfer for other purposes.
- Obtain agreement from Ecology and the PUD regarding the amount of water available for appropriation under the 1992 Agreement (estimated at 20,000 acre-feet). Initiate cost-reimbursement processing of the pending new water right applications that may be covered by the 1992 Agreement.
- Identify an adequate domestic water and fire-fighting supply as airport and planned developments proceed in the Howard Flats subbasin.

3.2 Water Quality Summary

Objectives:

- Develop and implement a comprehensive, long-term monitoring program to monitor key parameters that will ensure water quality sustainability throughout WRIA 47.
- Address water bodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.
- Inform and educate local communities and visiting populations about water quality protection.
- Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources.

Findings and Challenges:

- Understanding the water quality in WRIA 47 to improve the implementation of TMDL and other water quality goals requires high quality data to develop useful baseline summary and discern water quality trends.
- Water quality data are sporadic and unsuitable for assessing conditions and management decisions.
- The food web model requires a QAPP.

Recommended Actions for Water Quality:

- Calibrate the QUAL-2K water quality model with the first year of data to initiate the LTMP
- Prepare a Quality Assurance Project Plan (QAPP) for the food web bioaccumulation model to support the characterization and monitoring objectives of the LTMP.
- Initiate the LTMP using the initial modeling results to advance the implementation of the TMDLs for phosphorous and DDT/PCB.
- Evaluate the feasibility and benefits of including benzene as part of the Long Term Monitoring Plan.
- Inform and educate agencies and the public regarding LTMP objectives and findings to support watershed protection in WRIA 47.
- Evaluate the feasibility and priority for extending sanitary sewer to rural areas along the North and South Shores and around the Manson Lakes.
- Evaluate the feasibility and benefits for establishing an On-site Wastewater Management District to improve rural septic system performance in removing both bacteria and nutrients.
- Evaluate the feasibility and benefit of managing irrigation drain return flows that discharge to surface water.
- Promote land use practices and regulations for stormwater and clearing/grading to reduce unmanaged stormwater and sediment discharge to surface water

3.3 Habitat Summary

Objectives:

- Address ecological needs in WRIA 47 concurrently with water quality and quantity issues to support watershed planning.

Findings and Challenges:

- Fish population impacts include habitat degradation and loss; land development, conversion, and management; agricultural practices; fish-passage barriers; dam operations; flooding; species introductions; interspecific breeding; competition for resources; disease; harvest; and hatchery and stocking operations.
- These historic and current land use practices, which disturb or modify natural habitat functions, consequently alter water quality and/or quantity and availability and quality of habitat.

Recommended Actions for Habitat:

- Support the Lake Chelan Fishery Plan (LCFP) objectives to improve understanding of Lake Chelan fisheries and fisheries management, and address competing management approaches.

- Support the monitoring and understanding of habitat and species interactions and reproduction by coordinating LTMP activities with Lake Chelan Fishery Forum (LCFF) activities to implement the LCFP.
- Support habitat restoration efforts to improve limiting factors for both fish and wildlife.
- Support developing a detailed implementation plan that includes prioritized fish and wildlife actions.

4.0 STATE ENVIRORNMRENTAL POLICY ACT (SEPA) GAP ANALYSIS

This Chapter of the WRIA 47 Watershed Plan provides documentation of programmatic State Environmental Policy Act (SEPA) compliance specific to the Water Resource Inventory Area 47 (WRIA 47) Watershed Plan for adoption of the Plan by Chelan County.

This section provides the following information:

- A description of the process used to evaluate consistency of the WRIA 47 Watershed Plan with the statewide Programmatic Environmental Impact Statement (EIS) for Watershed Planning;
- A summary of the assumptions and judgments used in determining SEPA compliance of WRIA 47 Watershed Plan actions; and,
- Documentation of compliance of each action recommended in the WRIA 47 Watershed Plan with requirements for programmatic, non-project SEPA review.

4.1 WRIA 47 Watershed Plan Approach for Programmatic SEPA Compliance

The following options were considered for SEPA compliance in WRIA 47:

- **Adoption of the statewide programmatic Watershed Planning EIS and Determination of Significance (DS).** This is an option if the statewide programmatic Watershed Planning EIS adequately addresses all probable adverse impacts. The County (as lead SEPA agency) will use all or part of an existing document (the statewide programmatic Watershed Planning EIS) to meet all or part of the proponent's responsibilities under SEPA to prepare an EIS or other environmental document. A Determination of Significance (DS) is a written decision by the lead SEPA agency that the proposal is likely to have a significant adverse environmental impact and therefore an EIS is required (WAC 197-11-310 and WAC 197-11-360).
- **Adoption, DS, and Addendum.** Same as DS option above, with the addition of an addendum which provides local decision makers with additional local

information on compliance with the statewide programmatic Watershed Planning EIS.

- **Adoption, DS, and Supplemental EIS.** If the statewide programmatic Watershed Planning EIS addresses some but not all of the probable significant adverse environmental impacts, a supplemental EIS is necessary.
- **Determination of Non-Significance (DNS).** A DNS could be issued if it is determined that there are no probable significant adverse impacts associated with the recommended actions contained in the WRIA 47 Watershed Plan. In the event that a DNS includes mitigation measures as a result of the process specified in WAC 197-11-350, a **Mitigated Determination of Non-Significance (MDNS)** could be issued.

The qualifications, assumptions, and consistencies analyzed to achieve programmatic SEPA compliance for the WRIA 47 Watershed Plan are included within this section of the Plan (Section 4.0). This section is considered as the addendum to the statewide programmatic Watershed Planning EIS. The purpose of this section is to document the logic used in the SEPA gap analysis and the compliance of each action in the Plan with programmatic SEPA.

After reviewing the WRIA 47 Watershed Plan (Plan), Chelan County (as the lead SEPA agency) has determined they will adopt the statewide programmatic Watershed Planning EIS and issue a determination of significance (DS) to meet its responsibility to prepare a SEPA compliant review of the Plan. Adoption of the statewide programmatic Watershed Planning EIS is addressed with this section of the Plan. After adoption of the statewide programmatic Watershed Planning EIS, there is a seven (7) day waiting period before an action can be taken to approve the Plan (WAC 197-11-630).

4.2 SEPA and Watershed Planning

The State Environmental Policy Act (SEPA) (Chapter 43.21C RCW) was enacted by the State legislature to ensure that State and local agencies consider likely environmental consequences of proposed actions during decision-making processes concerning such activities. These consequences are considered during the SEPA review process.

Under SEPA rules, non-project actions are defined as governmental actions involving decisions on policies, plans, and programs. Such actions can include the adoption or amendment of policies, programs, and plans, such as Watershed Plans under Chapter 90.82 RCW. Any non-project action must be reviewed under SEPA unless specifically exempted.

The Washington State Department of Ecology (Ecology) published a Final Environmental Impact Statement for Watershed Planning under Chapter 90.82 RCW in August 2003 (Ecology, 2003). A copy of this statewide programmatic Watershed Planning EIS is available for review at the Chelan County Natural Resource Department offices in Wenatchee, WA and on the internet at http://www.ecy.wa.gov/biblio/0306013.html. Actions that could be included in local watershed plans are considered as SEPA "alternatives" in this statewide programmatic Watershed Planning EIS. Probable significant adverse environmental impacts that may be associated with these "alternatives" were also discussed in the statewide programmatic Watershed Planning EIS. If actions in a local watershed plan are consistent with the alternatives listed in the statewide programmatic Watershed Planning EIS, non-project programmatic SEPA requirements can be fulfilled by the statewide programmatic Watershed Planning EIS.

There are two SEPA compliance processes associated with actions in the WRIA 47 Watershed Plan:

1) Programmatic coverage of the County Watershed Plan approval process.

   Programmatic coverage of the WRIA 47 Watershed Plan is achieved through adoption of the statewide programmatic Watershed Planning EIS and the issuance of a Determination of Significance for the WRIA 47 Watershed Plan.

2) Non-programmatic SEPA for specific actions. Some specific project or non-project actions recommended in the WRIA 47 Watershed Plan, such as the initiation of a specific construction or management activity, will go through a separate SEPA review of the individual action itself at the time the action is implemented. The SEPA review completed at the current programmatic, non-project level of the SEPA process is adequate for County approval. Where alternatives in the statewide programmatic Watershed Planning EIS provide coverage for these actions, some of the documentation needed for the project-level SEPA approval process may reference the statewide programmatic Watershed Planning EIS and this section. However, the extent of the project SEPA process needed for each action is dependent entirely upon the nature of the specific action and its potential adverse environmental impacts. In some cases, these individual actions are in their early planning stages and are not sufficiently developed to make a SEPA judgment at the time of plan adoption by the County.

   This non-programmatic SEPA review of specific actions is not a prerequisite for the SEPA compliance necessary to achieve County approval of the WRIA 47 Watershed Plan, but will generally be necessary for plan implementation.

In summary, this section of the WRIA 47 Watershed Plan and adoption of the statewide programmatic Watershed Planning EIS fulfills the programmatic SEPA requirements necessary for County approval of the WRIA 47 Watershed Plan. SEPA compliance for individual (project and non-project) actions in the WRIA 47 Watershed Plan may also be granted during this approval process; however, some actions will be required to undergo specific project or non-project level review at the time that the individual action is implemented.

For federal actions, NEPA compliance is required when the action is implemented. However, this compliance is not a prerequisite for approval of the WRIA 47 Watershed

Plan by the County, nor is it necessary during the programmatic SEPA review. Additionally, the Watershed Planning Unit cannot obligate a federal agency to implement any actions, but can make recommendations to a federal agency.

4.3 SEPA Compliance for the WRIA 47 Watershed Plan

Plan Consistencies with the Statewide Programmatic Watershed Planning EIS

Recommended actions in the WRIA 47 Watershed Plan that are consistent with alternatives described in the statewide programmatic Watershed Planning EIS do not require supplemental information or additional consideration to achieve non-project programmatic SEPA compliance. A SEPA gap analysis was conducted where all alternatives in the statewide programmatic Watershed Planning EIS were reviewed and compared with recommended actions in the WRIA 47 Watershed Plan.

The alternatives from the statewide programmatic Watershed Planning EIS that were applied to the WRIA 47 Watershed Plan are listed below. Further descriptions of these alternatives and potential environmental impacts can be found in the statewide programmatic Watershed Planning EIS.

The following alternatives apply to one or more actions in the WRIA 47 Watershed Plan:

- WP 17 – Where adequate public water supplies are available, extend public water system service into areas served by exempt wells and require any new development to connect to such public water supplies.
- WP 28 – Request local governments or sewer utilities to construct and operate water reclamation and reuse facilities (e.g., reclamation plants and use areas) to reduce wastewater discharges to surface water bodies and improve water quality in receiving waters.
- WP 36 – Develop and implement a water quality public education program intended to prevent or reduce nonpoint pollution with focus on pollution sources associated with an urban setting, or with focus on pollution sources associated with a rural setting.
- WP 37 – Request local governments and Ecology to develop and operate water quality monitoring programs, including installation and maintenance of monitoring devices, to measure the extent of nonpoint pollution and/or measure the effectiveness of nonpoint pollution control measures.
- WP 40 – Request local governments to modify local regulations such as critical areas ordinances, stormwater regulations, and on-site sewage regulations to help reduce the potential for nonpoint pollution and/or to implement Total Maximum Daily Loads established for federal 303 (d) listed water bodies.
- WP 43 – Implement habitat improvement projects intended to "daylight" streams that are currently contained within enclosed channels.

- WP 45 – Request the Washington Department of Transportation, local governments, or other applicable agencies to remove or replace bridges, culverts, roadways, and other infrastructure as necessary to eliminate or reduce their impacts as fish passage obstructions and/or channel constrictions.
- WP 50 - Request local governments to develop regulations or programs to control sources of sediment that are not addressed through critical areas ordinances or other existing regulations and programs.

4.4 Other SEPA Assumptions and Qualifications

During the SEPA gap analysis, a number of recommended actions in the WRIA 47 Watershed Plan were found that are not described explicitly by alternatives in the statewide programmatic Watershed Planning EIS. However, it was determined that all of the actions not explicitly covered by the statewide programmatic Watershed Planning EIS either do not have adverse environmental impacts or do not require additional SEPA coverage at the programmatic level based on the qualifications and assumptions listed below. Therefore an additional EIS is not required.

The following are the qualifications and assumptions that are not specifically discussed in the statewide programmatic Watershed Planning EIS that are relevant to the WRIA 47 Watershed Plan:

Recommended actions that do not have a foreseeable "adverse environmental impact" do not require a SEPA alternative, or a statement of SEPA compliance. The following types of actions are listed in the WRIA 47 Watershed Plan and are not expected to have an adverse environmental impact:

- Improve the documentation of beneficial water use, inchoate rights, municipal
  water supply, irrigation water use, and irrigation return flow to update water balance estimates and monitor the effects of changes in water use to improve estimates of future water availability in WRIA 47 (Noted in Table 6 below as **coordination/collaboration/monitoring**)
- Initiate surface water and groundwater monitoring in the Wapato, Manson and
  lower Lucerne sub-basins to provide data to support water quality and habitat monitoring and improvement plans in WRIA 47 (Noted in Table 6 as **monitoring**)
- Promote joint comprehensive analysis and prioritization of future municipal/domestic use by large and small Group A systems, Group B systems, future irrigation use, and future commercial/industrial use (Noted in Table 6 as **collaboration/coordination**)
- Evaluate regional growth patterns, regional demands, inchoate water rights and water system connections for future/expanded service areas (Noted in Table 6 as **collaboration/coordination**)
- Evaluate potential future irrigation demands and transfers of water rights following conversion of agricultural land prior to transfer for other purposes (Noted in Table 6 as **collaboration/coordination**)

- Prioritize and establish quantities for the current 20,000 af PUD water right reservation and any future PUD water right reservations when needed (Noted in Table 6 as **collaboration/coordination**)
- Identify an adequate domestic water and fire-fighting supply as airport and planned developments proceed in the Howard Flats subbasin (Noted in Table 6 as **collaboration/coordination**)
- Evaluate the feasibility and benefit of managing irrigation drain return flows that discharge to surface water (Noted in Table 6 as **study**)

4.5 WRIA 47 Watershed Plan SEPA Compliance Table

Each action in the WRIA 47 Watershed Plan was evaluated against the statewide programmatic Watershed Planning EIS alternative or other analysis criteria used to achieve non-project programmatic SEPA compliance (**Table 6**). The table includes a SEPA analysis of the recommended actions presented in **Section 3** of this plan. The table is included within the text so that Chelan County can use this section of the Plan as supporting information to adopt the statewide programmatic Watershed Planning EIS and issue a determination of significance (DS) to meet its responsibility to prepare a SEPA compliant review of the Plan.

In some cases, more than one Watershed Planning alternative or a combination of qualifications and assumptions and alternatives are consistent with one action. Where combinations of alternatives and/or qualifications or assumptions are used, evidence for SEPA compliance is more robust.

Table 6. Results of SEPA Gap Analysis for WRIA 47 Watershed Management Plan and the Watershed Planning EIS

Water Quantity Recommended Action	SEPA Analysis
• Improve the documentation of beneficial water use, inchoate rights, municipal water supply, irrigation water use, and irrigation return flow to update water balance estimates and monitor the effects of changes in water use to improve estimates of future water availability in WRIA 47.	Collaboration, Coordination, Monitoring
• Initiate surface water and groundwater monitoring in the Wapato, Manson and lower Lucerne sub-basins to provide data to support water quality and habitat monitoring and improvement plans in WRIA 47.	Monitoring
• Use improved water balance estimates to support implementation of water quality studies and water quality management.	WP 37
• Promote joint comprehensive analysis and prioritization of future municipal/domestic use by large and small Group A systems, Group B systems, future irrigation use, and future commercial/industrial use.	Collaboration, Coordination
• Evaluate regional growth patterns, regional demands, inchoate water rights and water system connections for future/expanded service areas.	Collaboration, Coordination

• Evaluate potential future irrigation demands and transfers of water rights following conversion of agricultural land prior to transfer for other purposes.	Collaboration, Coordination
• Prioritize and establish quantities for the current 20,000 af PUD water right reservation and any future PUD water right reservations when needed.	Collaboration, Coordination
• Identify an adequate domestic water and fire-fighting supply as airport and planned developments proceed in the Howard Flats subbasin.	Collaboration, Coordination
Water Quality Recommended Actions	
• Calibrate the QUAL-2K water quality model with the first year of data to initiate the LTMP	WP 37
• Prepare a Quality Assurance Project Plan (QAPP) for the food web bioaccumulation model to support the characterization and monitoring objectives of the LTMP.	WP 37
• Initiate the LTMP using the initial modeling results to advance the implementation of the TMDLs for phosphorous and DDT/PCB.	WP 37
• Evaluate the feasibility and benefits of including benzene as part of the Long Term Monitoring Plan.	WP 37
• Inform and educate agencies and the public regarding LTMP objectives and findings to support watershed protection in WRIA 47.	WP 36
• Evaluate the feasibility and priority for extending sanitary sewer to rural areas along the North and South Shores and around the Manson Lakes.	WP 17
• Evaluate the feasibility and benefits for establishing an On-site Wastewater Management District to improve rural septic system performance in removing both bacteria and nutrients.	WP 28
• Evaluate the feasibility and benefit of managing irrigation drain return flows that discharge to surface water.	Study
• Promote land use practices and regulations for stormwater and clearing/grading to reduce unmanaged stormwater and sediment discharge to surface water	WP 40, WP50
Habitat Recommended Actions	
• Support the Lake Chelan Fishery Plan (LCFP) objectives to improve understanding of Lake Chelan fisheries and fisheries management, and address competing management approaches.	Collaboration, Coordination
• Support the monitoring and understanding of habitat and species interactions and reproduction by coordinating LTMP activities with Lake Chelan Fishery Forum (LCFF) activities to implement the LCFP.	Collaboration, Coordination
• Support habitat restoration efforts to improve limiting factors for both fish and wildlife.	WP 42, WP 43, WP 45
• Support developing a detailed implementation plan that includes prioritized fish and wildlife actions.	Collaboration, Coordination

Summary

This section of the WRIA 47 Watershed Management Plan provides documentation of compliance of the WRIA 47 Plan with the statewide programmatic SEPA requirements. This chapter is to be attached to the Determination of Significance filed for the Plan adoption action by Chelan County and provides local information relevant to the WRIA 47 Plan that is not ecplicity included in the statewide programmatic Watershed Planning EIS (Ecology, 2003).

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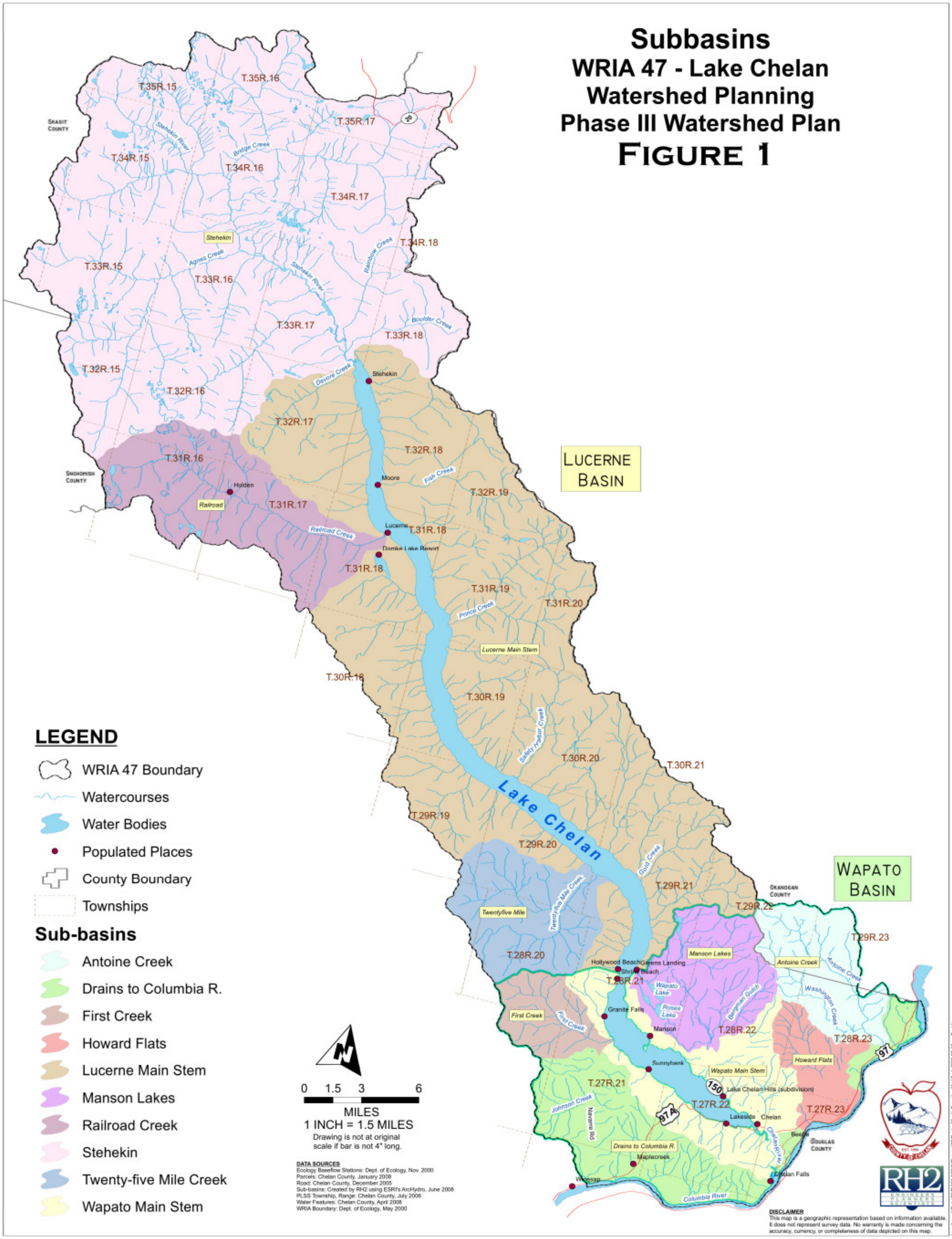
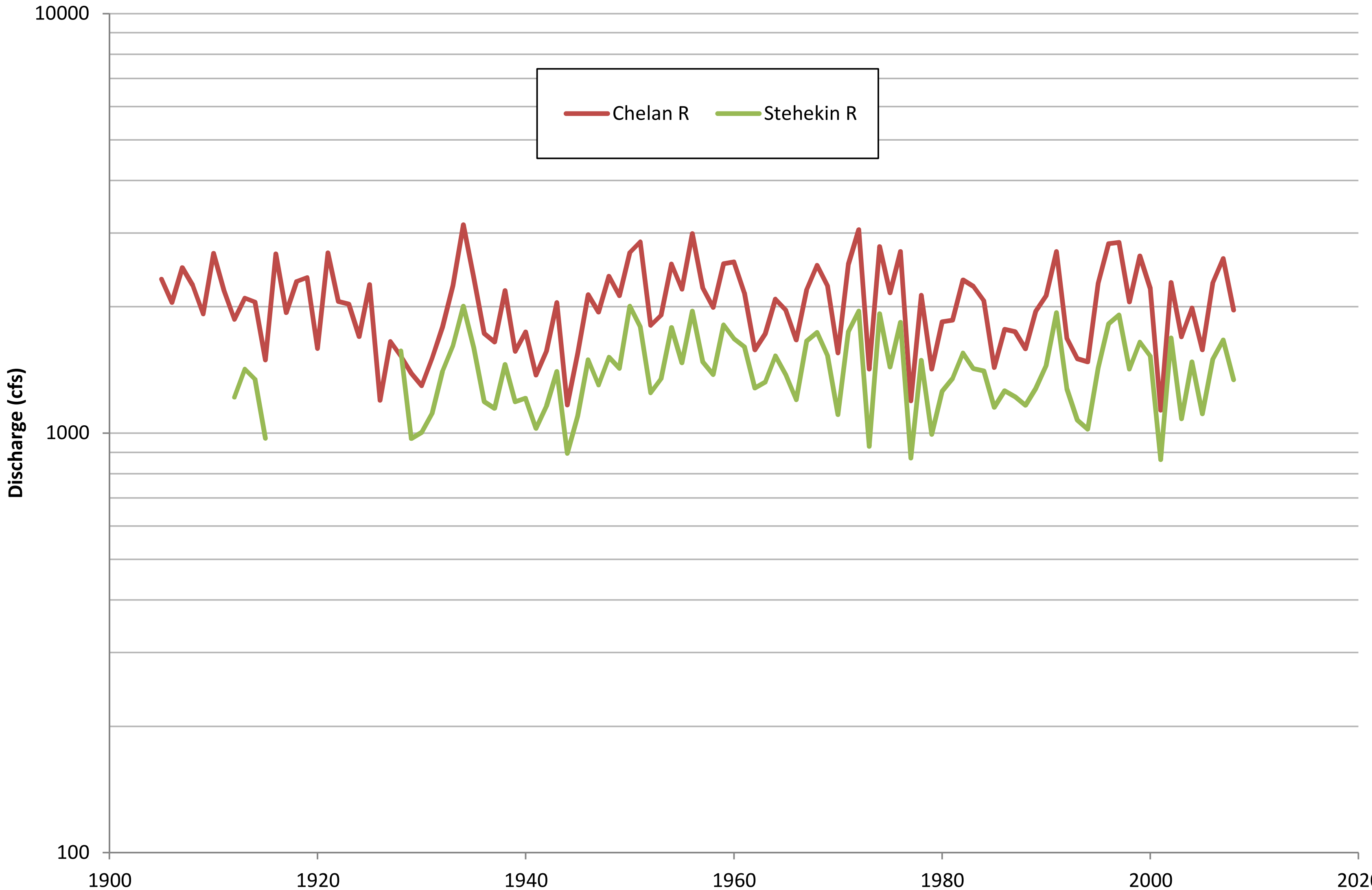

Subbasins
WRIA 47 - Lake Chelan
Watershed Planning
Phase III Watershed Plan
FIGURE 1
LEGEND
WRIA 47 Boundary
Watercourses
Water Bodies
Populated Places
County Boundary
Townships
Sub-basins
Antoine Creek
Drains to Columbia R.
First Creek
Howard Flats
Lucerne Main Stem
Manson Lakes
Railroad Creek
Stehekin
Twenty-five Mile Creek
Wapato Main Stem
Lucerne Basin
Wapato Basin
Lake Chelan
Stehekin
Holden
Moore
Lucerne
Domke Lake Resort
Railroad
Lucerne Main Stem
Twentyfive Mile
First Creek
Manson Lakes
Antoine Creek
Howard Flats
Wapato Main Stem
Drains to Columbia R.
Hollywood Beach
Greens Landing
Granite Falls
Manson
Sunnybank
Lake Chelan Hills (subdivision)
Lakeside
Chelan
Chelan Falls
Maplecreek
Columbia River
Chelan River
Skagit County
Snohomish County
Okanogan County
Douglas County
0 1.5 3 6
MILES
1 INCH = 1.5 MILES
Drawing is not at original
scale if bar is not 4" long.
DATA SOURCES
Ecology Baseflow Stations: Dept. of Ecology, Nov. 2000
Parcels: Chelan County, January 2008
Road: Chelan County, December 2005
Sub-basins: Created by RH2 using ESRI's ArcHydro, June 2008
PLSS Township, Range: Chelan County, July 2006
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2000
DISCLAIMER
This map is a geographic representation based on information available.
It does not represent survey data. No warranty is made concerning the
accuracy, currency, or completeness of data depicted on this map.

Figure 2 - Stehekin River and Chelan River Flow
Lake Chelan Watershed Plan - WRIA 47



Source: USGS Gauge Data

RH2 Engineering, Inc.

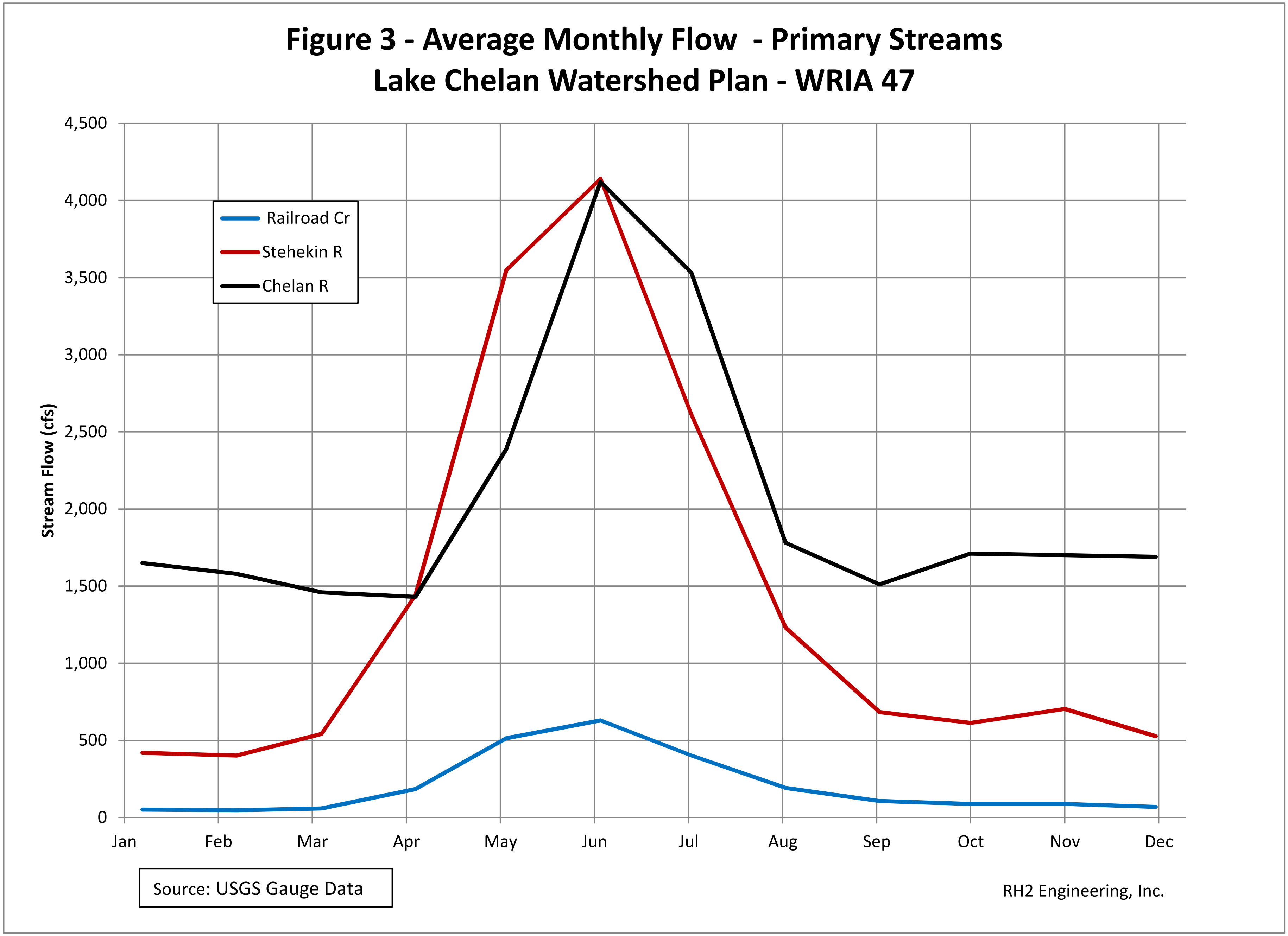


Figure 3 - Average Monthly Flow - Primary Streams
Lake Chelan Watershed Plan - WRIA 47
Stream Flow (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Railroad Cr
Stehekin R
Chelan R
Source: USGS Gauge Data
RH2 Engineering, Inc.

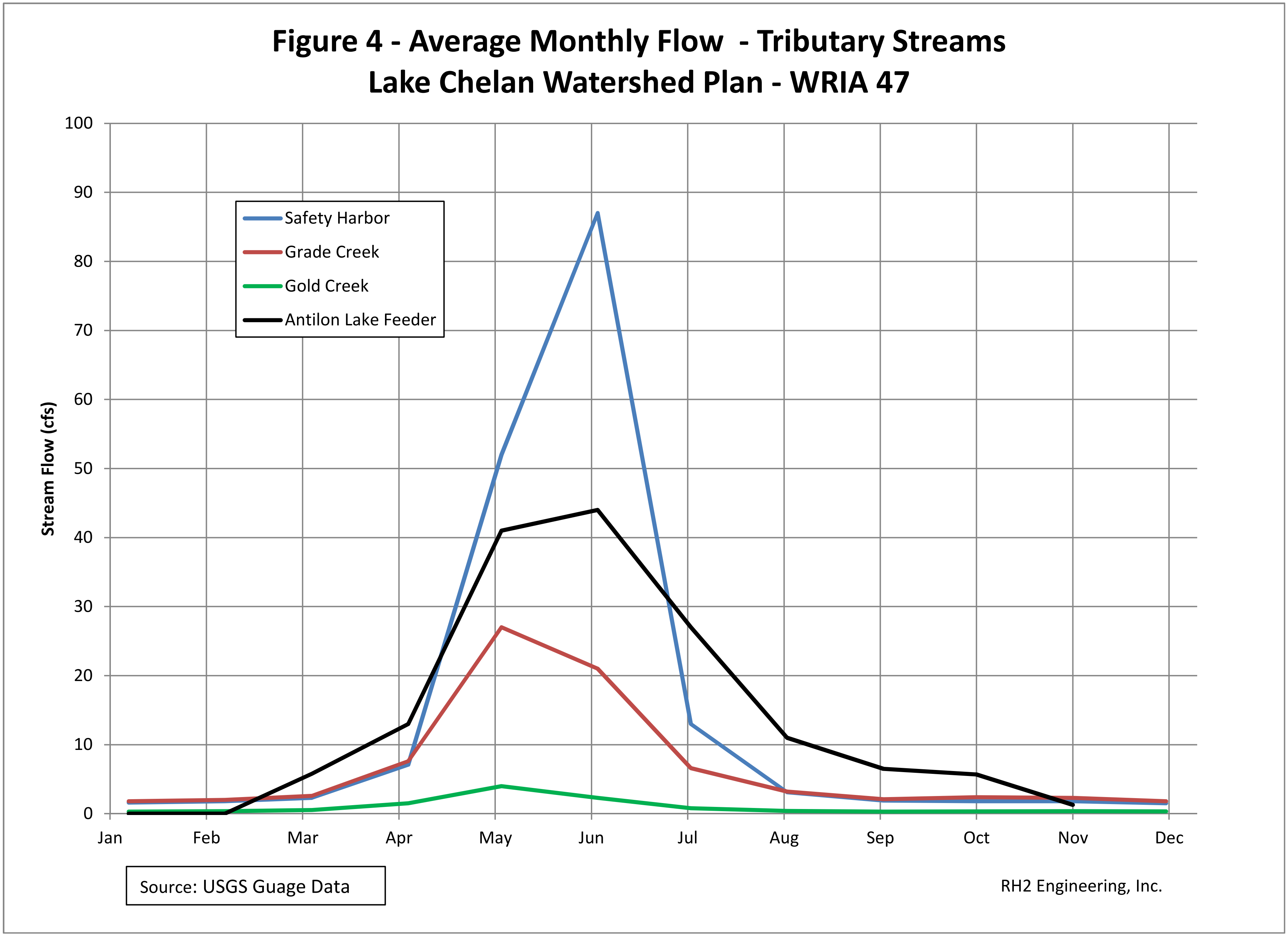


Figure 4 - Average Monthly Flow - Tributary Streams
Lake Chelan Watershed Plan - WRIA 47
Safety Harbor
Grade Creek
Gold Creek
Antilon Lake Feeder
Stream Flow (cfs)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Source: USGS Guage Data
RH2 Engineering, Inc.

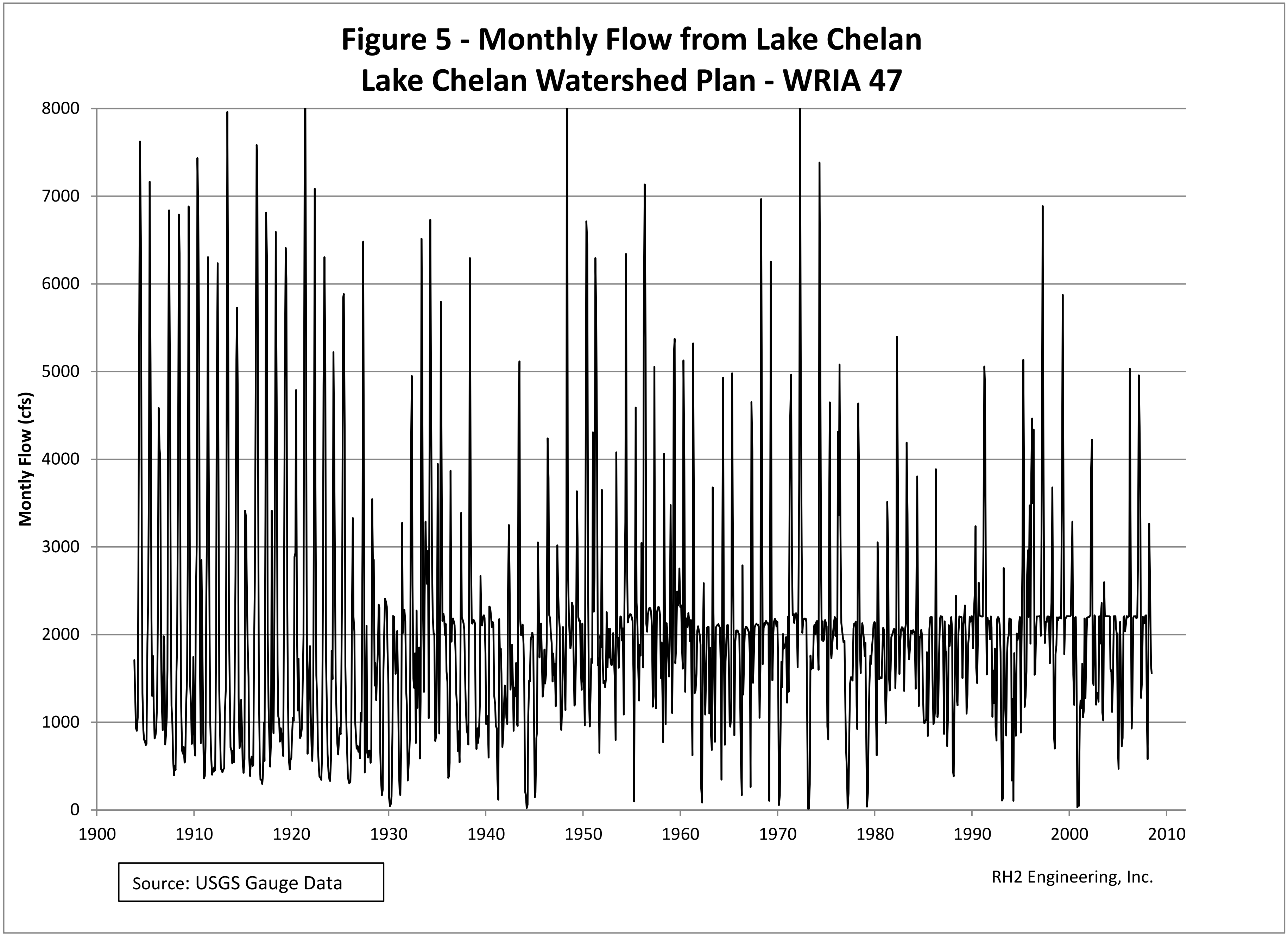


Figure 5 - Monthly Flow from Lake Chelan
Lake Chelan Watershed Plan - WRIA 47
Montly Flow (cfs)
8000
7000
6000
5000
4000
3000
2000
1000
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Source: USGS Gauge Data
RH2 Engineering, Inc.

Appendix A
Water Quantity Assessment Report

Table of Contents

FIGURES

Section 1 – Introduction

1.0 REGULATIONS AND APPLICATIONS

In 1998, the Washington State Legislature adopted the Watershed Management Act (Act) codified as Chapter 90.82 RCW. Watershed plans are developed at the local level by residents of the area with guidance and involvement from the Washington State Department of Ecology (Ecology), rather than being developed and directed by Ecology with local resident support.

The Legislature stated the following regarding the purpose of the Act.

> The purpose of this chapter is to develop a more thorough and cooperative method of determining what the current water resource situation is in each water resource inventory area of the state and to provide local citizens with the maximum possible input concerning their goals and objectives for water resources management and development (RCW 90.82.005).

1.1 PHASE 2 ASSESSMENT OBJECTIVES

The Act requires that the planning unit conduct a water quantity assessment to examine water supply and use and develop strategies for future use. Perhaps the most significant goal of the watershed assessment is to provide the most thorough understanding possible of the current water resources situation in Water Resource Inventory Area (WRIA) 47, consistent with the Legislature's direction. A thorough and accurate understanding of the water resource situation provides a strong foundation for any future efforts related to water resource management, whether it is to guide additional studies or obtain funding for a needed water resources project.

The first phase of the watershed assessment summarizes the water resources of WRIA 47 and identifies significant gaps in the data. RH2 previously identified and compiled data gaps during Phase 1 (RH2, 2008), and described their significance on the quantity assessment. The water and biological resources of the watershed have received significant attention during the previous decades, and much of this assessment compiles and summarizes the findings of these studies. New data that became available since the last compilation studies consist of additional water level and flow data, well drilling logs and water use data.

During Phase I, the Planning Unit resolved to conduct Phase II technical assessments, including the mandatory water quantity assessment, which addresses water available for future demands, and a water quality assessment (a separate report). The initiating governments chose not to pursue in-stream flow and habitat elements because they considered these issues essentially completed during previous efforts.

RH2 Engineering, Inc. (RH2) was contracted by the Chelan County Natural Resources Department (CCNR) to conduct the Phase 2 Water Quality Assessment. A technical subcommittee consisting of Planning Committee members and interested citizens was created to work with RH2 to provide local information and review technical elements.

The following Act requirements pertain to these technical assessments (Chapter 90.82.070 RCW).

Required Elements – Water Quantity Assessment

Assess water supply and use in the management area and develop strategies for future use including:

- An estimate of the surface and ground water present, taking into account seasonal and other variations;
- An estimate of the water represented by claims in the water rights claims registry, water use permits, certificated rights, existing minimum instream flow rules, federally reserved rights, and any other rights to water;
- An estimate of the surface and ground water actually being used;
- An estimate of the water needed in the future for use;
- An identification of the location of areas where aquifers are known to recharge surface bodies of water and areas known to provide for the recharge of aquifers from the surface; and
- An estimate of the surface and ground water available for further appropriation.

Develop strategies for increasing water supplies, which may include water conservation, water reuse, the use of reclaimed water, voluntary water transfers, aquifer recharge and recovery, additional water allocations, or additional water storage and water storage enhancements.

1.2 WRIA 47 WATERSHED PLANNING IMPLEMENTATION

The following summary was developed during Phase 1 planning.

The Planning Unit's vision is to recognize, inform, educate, monitor, understand and protect the unique water resource that is Lake Chelan; the ecological processes and pathways essential to maintaining this high quality water body; and the ways in which we can live on this lakeshore, enjoy this unique treasure and protect it for generations to come.

Mission
To develop an understanding of water and related aquatic and land resources by building trust and positive working relationships among diverse interests in the watershed to achieve a sustainable balance of economic, social and environmental values.

Goal
To implement a management plan for water use and protection that sustains the environmental, educational, economic and recreational values associated with a healthy lakeside community and watershed.

Objectives

1. Assess water supply, use and projected needs.
2. Develop and implement a comprehensive, long-term monitoring program of key parameters that will ensure water quality sustainability throughout the Lake Chelan Watershed.
3. Address water bodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.

4. Inform and educate local communities and visiting populations about water quality protection.
5. Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources.

The initiating governments view watershed planning as a complement to other water resource management efforts in the Lake Chelan Basin, including the implementation of re-licensing the Chelan Dam and work done by the Lake Chelan Water Quality Advisory Committee. Additionally, the WRIA 47 sub-basins adjacent to the Columbia River Basin overlap the management area for the Columbia River Basin Water Resource Management Program, which extends 1 mile from the Columbia River shoreline. Watershed planning under the Act is intended to augment such efforts without duplicating them. In fact, the Act requires that the Planning Unit review historical data and previous planning activities to ensure that any products are incorporated into the watershed planning effort and that the watershed planning effort does not duplicate work already performed.

Section 2 – WRIA 47 Characteristics

The Water Resource Inventory Area (WRIA) 47 watershed has undergone several basin-wide reviews by various entities for various purposes since the mid-1960s. In the last decade, water quantity and quality studies were conducted to support the Federal Energy Regulatory Commission (FERC) relicensing effort. The relicensing process began in 1998, and the final license application was submitted to the FERC in June 2004. The Phase 2 Water Quantity Assessment relies upon the findings of these studies and incorporates recent water resource and water use data. The *Phase 1 Water Quantity Report* (RH2, 2008) included a literature review of water quantity studies in the watershed.

The area occupied by WRIA 47 (also referred in this report as the "watershed," or "management area") comprises 1,044 square miles, of which 90 percent or 937 square miles includes Lake Chelan and its tributary sub-basins; the remaining 10 percent consists of sub-basins that drain to the Columbia River. One primary tributary, the Stehekin River, and one secondary tributary, Railroad Creek, discharge 85 percent of WRIA 47 runoff into Lake Chelan. The management area consists of ten sub-basins shown on **Figure 2-1**. Characteristics of the sub-basins are summarized in Section 2.1. Approximately 1.8 percent of WRIA 47 lies within Okanogan County.

WRIA 47 has political and physical characteristics similar to other east-slope Cascade watersheds. Most of the watershed is under Federal management, primarily by the US Forest Service and National Park Service. The watershed includes glaciers and rugged mountains at the highest elevations, dense fir and open ponderosa pine forests, wide expanses of shrub-steppe, and narrow riparian zones in lower elevations. The largest communities have developed along the lake shoreline, and nearby hillsides are irrigated for orchard and pasture. WRIA 47 is distinct among other central Washington watersheds for its inclusion of Lake Chelan, a very large lake/reservoir that is managed for multiple uses including power, recreation, irrigation, potable supply, historic and cultural preservation, fisheries, wildlife and habitat. Lake levels and flows are strictly managed by the Chelan County PUD under FERC license to balance the water demands for each use.

Elevations in WRIA 47 range from 700 feet at the Columbia River to 9,511 feet at Bonanza Peak. Approximately 69 percent of WRIA 47 is above an elevation of 3,000 feet, and 47 percent of the basin lies above an elevation of 5,000 feet. Landforms consist of the classic U-shaped glacially-carved valleys of Lake Chelan, the Stehekin River and smaller tributaries in the higher elevation sub-basins, which are surrounded by high ridges and steep cliffs. Lower elevation sub-basins are narrower incised valleys that are tributaries to Lake Chelan and the Columbia River, bounded by rolling hills near the lake's terminus at the City of Chelan, and gravel terraces along the Columbia River.

The 2000 Washington State Census data determined a population of 11,706 for WRIA 47 (excluding the Okanogan County portion of the watershed). The Census forecasted a population of 13,104 for 2008 and 15,650 by 2025. Most residents work within the watershed and live within the Wapato Main Stem and Manson Lakes Sub-basins.

Power generation, tree fruit agriculture and recreation are the predominant land uses in the basin, followed by year-round and seasonal residential use.

Lake Chelan and its immediate surroundings are the result of the complex interaction between two glacial masses. The lake was formed approximately 18,000 to 15,000 years ago during the Vashon/Wisconsin glacial period. During this time, the Chelan Glacier moved down the valley from the Cascade Crest, and the Okanogan-Columbia Valley lobe of the Cordilleran ice sheet extended upward from the south. The two glaciers approached each other and nearly met at Wapato Point and a constriction known as "The Narrows" (a shallow sill 135 feet below the surface of the lake at its narrowest part). The approach and recession of these two glaciers caused erosion in the mid and upper portion of the lake, and geologic moraine deposits at the lower end of the lake. Together, these erosional processes created Lake Chelan (Kendra and Singleton, 1987, and Hillman and Giorgi, 1999 in Viola and Foster 2000). The lake now consists of two basins: the Lucerne basin, which is deep and fjord-like and extends north from The Narrows for 38 miles; and the Wapato basin, which is relatively wide and shallow in comparison (maximum depth of 400 feet) and extends for 12 miles south of The Narrows (Hillman and Giorgi, 1999 in Viola and Foster, 2000).

Lake Chelan is a regulated reservoir under FERC license that was re-authorized on November 6, 2006. The reservoir project is described in the license as follows:

> The Federal Power Commission (FPC) issued the original license for the Lake Chelan Project on May 8, 1926. On May 21, 1981, the Federal Energy Regulatory Commission (the successor to FPC) issued Chelan PUD a new license that was made retroactive to 1974; the license expired on March 31, 2004. Since that time, project operations have continued pursuant to an annual license.
>
> The Lake Chelan Project consists of (a) Lake Chelan, a 1,486-foot deep, 55-mile-long natural glacial lake that was raised 21 feet by the construction of the dam to a normal maximum water surface elevation of 1,100 feet mean sea level (msl); (b) a 40- foot-high, 490-foot-long concrete gravity dam; (c) a reinforced-concrete side discharge intake structure that is integral with the dam; (d) a 14-foot-diameter, 2.2-mile-long power tunnel; (e) a 45-foot-diameter by 125-foot-high steel surge tank; (f) a 90-foot-long penstock that transitions from 14 feet in diameter to 12 feet in diameter before bifurcating to two 90-foot-long, 9-foot-diameter steel penstocks; (g) a powerhouse containing two vertical-shaft, Francis-type turbine generators with a rated capacity of 24,000 kilowatts (kW) each for a total rated capacity of 48,000 kW; and (h) a 1,700-foot-long excavated tailrace adjacent to the confluence of the Chelan River and the Columbia River that returns the project flows to the Columbia River. The average annual electric generation by the project was 380,871 megawatt-hours (MWh) for the 20-year period, 1980-1999.
>
> The Lake Chelan Project, which can be operated locally or remotely from Chelan PUD's Wenatchee Dispatch Center, operates at full or near full capacity almost year-round. Chelan PUD operates the project to maintain reservoir elevations between 1,100 and 1,079 feet msl, with the reservoir maintained above 1,098 feet for most of the summer recreation period. The reservoir is drawn down annually for power generation and storage of spring snowmelt beginning in early October, with the lowest lake levels being reached in April. The lake is refilled through May and June, to attain an elevation of 1,098 feet on or before June 30, where it is maintained

above 1,098 feet through September 30. Spills typically occur during May, June, and July, when inflows exceed the hydraulic capacity of the powerhouse units (2,300 cubic feet per second (cfs)) or when generation is curtailed. Water is spilled over the spillway into the 4.5-mile-long reach of the Chelan River that is bypassed by the project.

Under the new license, Chelan PUD has slightly greater flexibility in managing lake levels by establishing target elevations to be achieved between May 1 and October 1, rather than a fixed elevation by a certain date. Chelan PUD manages minimum lake elevations based on snow pack conditions, lake levels, predicted precipitation and runoff conditions, and operational objectives of maintaining minimum instream flows in the Chelan River, reducing high flows (greater than 6,000 cfs) in the Chelan River, providing usable lake levels for recreation (between 1,090 and 1,098), and ensuring the project can pass the probable maximum flood without dam failure, among other objectives. The previous license did not require a minimum flow release to the bypassed reach of the Chelan River. Chelan PUD provides a minimum flow for the entire bypassed reach, supplemented with pumping of additional water from the tailrace into the lower portion of the Chelan River (Reach 4) to improve spawning habitat for listed salmon and steelhead. The minimum flow varies depending on the time of year and whether it is a dry, normal, or wet water year.

Lake Chelan is a 32,560-acre reservoir at normal maximum water surface elevation of 1,100 feet msl, with a gross storage capacity of 15.8 million acre-feet (AF) and a useable storage of 677,400 AF between elevations 1,079 and 1,100. Approximately 2,000 acres of land lie within the Lake Chelan Project boundary which follows the 1,100-foot contour line from the upper end of Lake Chelan near Stehekin, Washington, to the City of Chelan then continues down both sides of the 4.5-mile-long bypassed reach of the Chelan River to the confluence of the Chelan and Columbia rivers. About 1,300 acres of the project lands are inundated and project facilities occupy the other 700 acres. The project lands are owned by the Forest Service, Park Service, several state agencies, Chelan PUD, and private property owners. Approximately 465.5 acres are inundated federal lands.

FERC License Background (Chelan PUD, 2008)

The FERC Order on Offer of Settlement and Issuing New License (License) for the Lake Chelan Hydroelectric Project No. 637 (Project) was issued November 6, 2006 to the Public Utility District No. 1 of Chelan County (Chelan PUD). An Order on Rehearing for the Project was issued April 19, 2007.

On March 28, 2002 Chelan PUD entered into a Settlement Agreement (Agreement) and Lake Chelan Comprehensive Management Plan with the US Department of Agriculture Forest Service (USFS), National Park Service (NPS), National Marine Fisheries Service (NMFS), US Fish and Wildlife Service, (USFWS), Washington State Department of Fish and Wildlife (WDFW), Washington State Department of Ecology (Ecology), the Confederated Tribes of the Colville Reservation (CCT), American Whitewater and the City of Chelan. The Agreement was filed with the FERC on October 8, 2003 and was incorporated by the FERC as part of the License Order.

Chelan PUD and Ecology successfully defended the Project's water quality certification during a challenge before the State Pollution Control Hearing Board, and on April 21, 2004, Ecology amended and re-issued water quality certification for the Project.

The Chelan PUD issues an annual report summarizing the status of implementing the license measures and summarizing the work plan for the following year (Chelan PUD, 2008). Article 401(a) of the FERC License Order required that several plans be filed with the FERC on or before November 6, 2007 for approval prior to implementation. Each forum met during 2007 with the goal of completing the required resource plans for submittal to the FERC.

Following is a list of resource plans or reports submitted to the FERC and approved as of March 1, 2008.

- *Reservoir Drawdown Limitation and Safety Report* (filed January 8, 2007)
- *Traditional Cultural Properties Management Plan* (plan due November, 1 2008)
- *Threatened Endangered Species Protection Plan* (filed May 4, 2007, approved November 28, 2007)
- *Operations Compliance Monitoring Plan* (filed May 4, 2007, approved November 30, 2007)
- *Quality Assurance Project Plan* (filed May 4, 2007, approved November 30, 2007)
- *Annual Lake Level Report* (submitted November 6, 2007, accepted November 27, 2007)
- *Lake Chelan Fishery Plan* (filed November 6, 2007, approved December 4, 2007)
- *Erosion Control Plan* (Forest Service) and Site Specific Plan (filed November 6, 2007, approved January 4, 2008)
- *Annual Report of Activities* per Programmatic Agreement (filed December 4, 2007)

Below is a list of resource plans or reports with approval by the FERC pending as of March 1, 2008:

- *Stehekin Area Implementation Plan* (filed November 6, 2007)
- *Wildlife Habitat Plan* (filed November 6, 2007)
- *Recreation Resources Plan* (filed November 6, 2007)

2.0 SUB-BASINS

Each of the ten sub-basins in WRIA 47 has distinct elevation, geology, weather, land use and vegetation characteristics. **Table 2-1** summarizes characteristics for each sub-basin. The following text summarizes the sub-basins from north to south.

Stehekin Sub-basin
The Stehekin Sub-basin has the largest area and the highest elevation in WRIA 47 at Bonanza Peak at 9,511 feet. Much of the upper portion of this sub-basin consists of glaciated tributary valleys and surrounding steep ridges above and below timberline, as well as the deep and broad Stehekin River Valley. Upland areas are covered with subalpine forest and the Stehekin Valley includes a mixture of riparian and subalpine vegetation. Most of the Stehekin Sub-basin is managed by the USFS and NPS, except for small private in-holdings near the Town of Stehekin. The Stehekin Sub-basin terminates at the confluence with Lake Chelan.

Railroad Creek Sub-basin

The second largest sub-basin is similar to the Stehekin Sub-basin but smaller in scale. The Railroad Creek Sub-basin is also under Federal land management, except for historic mining claims now patented for private use, and the villages of Holden and Lucerne.

First Creek and Twenty-five Mile Creek Sub-basins

These lower elevation tributary sub-basins exhibit broad valleys and ridges unlike the topography of upper elevation sub-basins. Vegetation consists of a mixture of pine forest, deciduous riparian and shrub-steppe species. The highest elevations attain 6,000, feet but much of the sub-basin lies below 3,000 feet. Land use is wholly or partially managed by the USFS and Washington State, and much of the lower elevations of the First Creek Sub-basin are privately owned.

Lucerne Main Stem Sub-basin

The Lucerne Main Stem Sub-basin consists of steep slopes above Lake Chelan and numerous small to minor tributaries. Higher elevations of the sub-basin exhibit alpine glacial headwalls that rise to elevations exceeding 8,000 feet and steep valleys that discharge to Lake Chelan. Further down lake towards Manson, the tributaries were truncated by the Chelan Glacier, resulting in relatively broad upland valleys connected to the lake by steep slopes and narrow stream channels. The Lucerne Main Stem is connected to the Wapato Main Stem at the lake narrows. Most of the Lucerne Main Stem Sub-basin is under USFS management, except for small private parcels along the shoreline. The sub-basin is covered by a range of vegetation from subalpine and mixed pine forest to shrub-steppe areas cut by riparian streams.

Wapato Main Stem Sub-basin

The Wapato Main Stem Sub-basin is comprised of valleys and ridges that are broader than those present in the Lucerne Main Stem Sub-basin. The highest elevation attains 3,500 feet, and the terrain is more characterized by recent erosion of slopes and valleys rather than historic glacial activity. The lower elevations and broad, rolling topography promote extensive irrigation and residential use along and above the lake shoreline. Consequently, much of the basin is under private or municipal ownership. Irrigation has extensively modified the natural cover from shrub-steppe to orchard and pasture.

Manson Lakes Sub-basin

The Manson Lakes Sub-basin has experienced the greatest amount of modification from natural shrub-steppe to irrigated orchard. The sub-basin contains several large lakes including Roses, Dry, Wapato and Antilon; the latter two were historically used to artificially store water for irrigation. The sub-basin consists primarily of rolling hills underlain by glacial geologic units and thick layers of soil that promote agriculture in the basin. Upper elevations rise to more than 5,500 feet in elevation and are covered with mixed pine-fir forests.

Columbia River Tributaries

The Columbia River Sub-basins are directly connected to the Columbia River rather than to Lake Chelan. These sub-basins have limited water resources and domestic and irrigation supplies rely either on small groundwater wells or the Columbia River. The sub-basins are comprised of relatively steep slopes that lead to terraces above the river and are covered by shrub-steppe vegetation. Ephemeral streams flow occasionally during periods of spring melt and winter rains.

Howard Flats Sub-basin

The Howard Flats Sub-basin is connected to the Columbia River. The broad terraces of the lower sub-basin support irrigation, and much of the water used in the sub-basin derives from the Columbia River. The upper sub-basin is comprised of shrub-steppe and pine forest at higher elevations of approximately 3,000 feet. Much of the lower elevation terrain is under private ownership, and upland areas are managed by Washington State or the US Bureau of Land Management for multiple uses.

Antoine Creek Sub-basin

The Antoine Creek Sub-basin is similar in character to the Howard Flats although lacking the broad irrigated terraces. The headwaters of Antoine Creek rise to an elevation of 5,600 feet. Spring runoff from the headwaters may not reach the Columbia River due to diversion, infiltration or evapotranspiration. The Antoine Creek Sub-basin lies partially within Okanogan County, and the water rights of the basin were adjudicated in 1928. Land use is managed primarily for agriculture, livestock and forest products, either by private ownership in the lower elevations or under Federal management in the upper elevations.

Table 2-1 Sub-Basin Characteristics

Sub-basin	Area (acres)	Minimum Elevation (feet)	Maximum Elevation (feet)
Stehekin	218,576	1,100	9,511
Lucerne Main Stem	209,048	1,100	8,590
Railroad Creek	41,553	1,100	9,511
Columbia River Tributaries	35,726	710	3,800
Manson Lakes	24,974	1,100	5,850
Lake Chelan	33,344	1,079	1,100
Wapato Main Stem	30,548	1,100	3,600
25-Mile Creek	27,078	1,100	7,150
Antoine Creek	21,059[1]	710	5,600
Howard Flats	11,807	710	3,400
First Creek	11,634	1,100	6,850
Total	**653,713**		

[1] Plus 3,290 acres in Okanogan County

2.1 LANDCOVER AND LAND USE

Less than 4 percent of the land area in WRIA 47 is developed, primarily in and around the communities of Chelan and Manson in the Wapato Main Stem and Manson Lakes Sub-basins, and Chelan Falls at the confluence with the Columbia River. Smaller communities are developed near the tributaries and near their confluence with Lake Chelan, including Stehekin, Lucerne and Holden Village. Land cover in the Lucerne Main Stem Sub-basin ranges from shrub-steppe in the lower and middle elevations, whereas forest and bare rock outcrops cover much of the higher elevations in the Stehekin Sub-basin. Crop cover that is mostly comprised of orchards is extensive in the Manson Lakes and Wapato Main Stem Sub-basins (see Section 4). The Wapato Main Stem Sub-basin is dominated by shrub-steppe land cover with extensive orchards and relatively dense urban cover in the lower elevations within about 1 mile of the Columbia River. Shrub-steppe land cover in the First Creek and Twenty-five Mile Creek Sub-basins is found on slopes that are too steep to be used for agriculture. The Howard Flats and Antoine Sub-basins are comprised of flat terraces surrounded by steep slopes; most of the relatively flat areas in the sub-basins are covered by orchard.

Current zoning information from the Chelan County Planning Department indicates primary land uses in each sub-basin (**Figure 2-2**). About 80 percent of land use in the watershed is zoned Forest Land, 17 percent as Rural Residential/Resource (including agriculture) and 2 percent as Commercial Agriculture.

Table 2-2 – Land Use in WRIA 47 (Acres)

Land Use	Forest/Public	Rural Res/ Resource	Agriculture	Urban	Industrial	Total
Stehekin	203,754	14,821	-	-	-	218,576
Lucerne Main Stem	198,971	9,853	115	-	-	209,048
Railroad	41,553	-	-	-	-	41,553
Columbia River Tributaries	4,395	28,129	2,229	592	85	35,726
Manson Lakes	5,511	14,300	5,124	3	3	24,975
First Creek	10,847	780	-	-	-	11,634
Wapato Main Stem	1,804	21,207	2,351	5,040	8	30,548
25-mile Creek	26,157	666	-	-	-	27,077
Antoine Creek	1,313	9,946	106	-	-	12,339[1]
Howard Flats	133	9,846	1,692	49	81	11,800
Total	**491,970**	**106,693**	**11,617**	**5,684**	**177**	**616,985**

[1]Within Chelan County

2.2 CLIMATE

The climate of WRIA 47 is moist to semi-arid and characterized by mild to hot dry summers and mild to severe winters. The average summer maximum temperature for July in Chelan is 85°F, and the average winter minimum in Holden Village is 15°F (WRCC, 2009). Precipitation and temperature vary widely depending on the elevation and proximity to the Cascade Crest. Winds typically are funneled down the lake valley in a southeasterly and easterly direction towards the Columbia River Basin, where warm air masses are rising. This pattern causes increased wind speeds in the evenings, especially on the north shore of Lake Chelan.

Average annual precipitation in the area ranges from a high of 150 inches near the crest of the Cascade Mountains to a low of 11 inches in the City of Chelan, near the Columbia River (Beck, 1991). Total annual precipitation at Stehekin, at the head of the lake, averages 34 inches, the majority of which falls as snow from November through March (FERC, 2001).

The climate in WRIA 47 ranges from semi-arid in the lower elevations to sub-alpine in the higher elevations. Prevailing westerly winds bring moisture across the Cascade Mountains, and higher elevations and west-facing slopes intercept most of the precipitation falling in the watershed. Most precipitation falls as snow above 3,000 feet during the months of October through April. Average winter and summer temperatures range from 22 to 53ºF at Rainy Pass to 30 to 70ºF at Chelan (**Table 2-3**), (Natural Resource Conservation Service [NRCS], 2006; Western Regional Climate Center, 2009). Temperature and precipitation are discussed in greater detail below.

Three climate recording stations lie within WRIA 47, and a number are positioned a few miles outside the watershed (**Figure 2-3**; **Table 2-3**). The Chelan (Lakeside) station, with a period of record from 1890 to date, lies at an elevation of 1,120 feet on the south shore of Lake Chelan and southwest of the City of Chelan. The Stehekin station, with a period of record from 1906 to date, lies at an elevation of 1,270 feet in the Stehekin River Valley, approximately 3 miles from the mouth of the Stehekin River. The Holden Village station, with periods of record from 1930 to 1957 and 1962 to 2008, lies at an elevation of 3,220 feet in Holden Village in the Railroad Creek valley, approximately 8 miles from the mouth of the Railroad Creek.

Three SNOTEL stations that lie within the Stehekin Sub-basin have collected snowfall and temperature data since approximately 1980. The Park Creek Ridge, Rainy Pass and Lyman Lake stations are at elevations of 4,600, 4,900 and 6,000 feet, respectively.

Table 2-3 –Temperature Summary in WRIA 47

Location	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Cooperative Stations														
Stehekin	Max T (ºF)	33.2	39.0	47.8	59.1	68.4	75.0	83.0	81.5	71.9	57.5	42.2	34.2	57.7
(1906 to 2008)	Min (ºF)	22.8	25.0	29.2	35.4	42.2	48.4	53.0	52.3	44.9	36.7	30.1	25.3	37.1
Elev. 1,270 ft	Mean (ºF)	28.0	32.0	38.5	47.2	55.3	61.7	68.0	67.0	58.4	47.1	36.2	29.8	47.4
	Ppt (in)	5.9	4.0	2.8	1.4	0.9	0.8	0.5	0.6	1.1	3.0	6.0	6.9	34.0
Holden Village	Max T (ºF)	30.4	37.0	43.9	51.8	61.8	69.2	77.4	77.4	68.9	54.8	37.2	29.6	53.3
(1980 to 2008)	Min (ºF)	**15.4**	17.8	22.6	27.9	34.0	40.3	44.0	44.0	37.7	30.5	23.4	15.5	29.4
Elev. 3,220 ft	Mean (ºF)	22.9	27.4	33.3	39.9	48.0	54.8	60.7	60.7	53.3	42.6	30.3	22.5	41.3
	Ppt (in)	7.0	4.6	3.1	1.5	1.1	1.1	0.7	1.1	1.5	3.4	6.8	7.5	39.4
Chelan	Max T (ºF)	32.8	40.6	51.1	61.1	70.3	77.6	**85.3**	85.0	75.1	61.2	44.3	34.0	59.9
(1890 to 2008)	Min (ºF)	22.7	26.7	32.7	39.8	47.8	55.3	60.5	59.6	50.6	40.3	31.8	25.0	41.1
Elev. 1,120 ft	Mean (ºF)	27.7	33.6	41.9	50.5	59.0	66.5	72.9	72.3	62.9	50.7	38.0	29.5	50.5
	Ppt (in)	1.5	1.1	0.9	0.7	0.8	0.7	0.3	0.4	0.4	0.7	1.6	1.9	10.9
SNOTEL Stations														
Lyman Lake	Max T (ºF)	21.9	23.3	26.6	31.3	37.5	42.9	51.0	50.8	45.8	34.8	27.2	21.1	34.5
(1980 to 2008)	Ppt (in)	12.8	9.1	8.1	5.5	3.4	2.6	1.5	1.6	2.9	6.7	11.1	12.3	77.7
Elev. 5,980 ft														
Park Cr Ridge	Max T (ºF)	24.1	26.7	30.0	35.3	42.6	48.7	57.0	57.9	51.9	40.7	34.8	23.0	39.4
(1979 to 2008)	Ppt (in)	11.7	8.2	6.7	3.6	2.1	1.7	1.0	1.1	2.3	5.3	11.8	11.6	66.9
Elev. 4,600 ft														
Rainy Pass	Max T (ºF)	21.8	23.9	27.7	33.0	39.4	41.4	53.2	52.5	46.2	36.7	28.7	29.4	36.2
(1980 to 2008)	Ppt (in)	8.9	6.7	5.9	3.6	2.9	2.3	1.4	1.2	2.0	5.1	9.8	8.0	57.7
Elev. 4,890 ft														

Figure 2-4 illustrates the monthly average temperatures at the Lyman Lake SNOTEL, Holden Village, Stehekin and Chelan stations.

2.3 PRECIPITATION

Except for limited pumping from the Columbia River to adjacent sub-basins, precipitation provides all of the total water input to the WRIA 47 hydrologic system. Precipitation has been measured at several points in WRIA 47 since 1890. Precipitation patterns are dominated by winter snowfall at elevations above 3,000 feet for more than half of the watershed area, which melts and runs off April through June. Base flow occurs during July and August. Average monthly precipitation at the Lyman Lake SNTOEL, Holden Village, Stehekin and Chelan station are shown in **Figure 2-5**.

Average annual precipitation measured in WRIA 47 ranges from 11 inches at Chelan to 77 inches at Lyman Lake SNOTEL (**Table 2-3**). These weather stations are located 50 miles apart and differ in elevation by over 4,800 feet (**Figure 2-3**). Point data represented by these two weather stations and spatial data from a digital elevation model were used in the Parameter-elevation Regression on Independent Slopes Model (PRISM; Oregon Climate Service [OCS], 2006) to produce a gridded estimate of average annual precipitation throughout the watershed (**Figure 2-3**). Area-weighted averages for annual precipitation during dry and wet years were derived from two representative water years, 1944 and 1996, respectively (WRCC, 2009)**.** The gridded estimates and representative water year data were also used to estimate the total volume of precipitation into each sub-basin.

The average annual precipitation for WRIA 47 is approximately 45 inches. Annual dry-year precipitation is approximately 30 inches and annual wet-year precipitation is 51 inches. The annual volume of precipitation in WRIA 47 is approximately 2.4 million AF during an average year, 1.6 million AF during a dry year and 2.7 million AF during a wet year. **Table 2-4** summarizes precipitation data for the average of the period of record (1916 to 2008) and for representative dry (1944) and wet (2006) years.

Table 2-4 – Average, Dry and Wet Year Precipitation

Sub-basin	Average Annual Rainfall Normal Year (AFY)	Average Annual Rainfall Dry Year - 1944 (AFY)	Average Annual Rainfall Wet Year - 2006 (AFY)
Stehekin	1,246,100	772,067	1,360,143
Lucerne Main Stem	683,090	453,125	778,375
Railroad Creek	173,966	119,129	211,377
Columbia River Tributaries	51,093	38,433	56,695
Lake Chelan	69,427	48,599	76,370
Wapato Main Stem	40,390	31,698	46,808
25-mile Creek	77,227	54,843	85,194
Manson	45,075	29,523	42,071
Antoine	41,160	26,883	39,742
Howard Flats	16,982	12,364	19,010
First Creek	28,547	19,678	29,708
Total	**2,444,509**	**1,586,664**	**2,715,786**

The following assumptions were made in the precipitation estimates.

- Maximum and minimum values assigned to each precipitation band were taken from PRISM data and is represented by a single average value.
- Precipitation distribution is primarily controlled by elevation.

In addition this estimate does not consider:

- The influence of micro-climates within the basin; or
- Contributions from rime ice derived from fog and clouds that could contribute up to 3 to 4 inches per year at the highest elevations (USFS, 1969)

2.4 TEMPERATURE AND EVAPOTRANSPIRATION

Temperature
Air temperature generally cools with increased elevation at what is known as the wet lapse rate (2.7 ºF per 1,000 feet of increased elevation). Average monthly and annual temperatures at selected weather station and SNOTEL sites are summarized in **Table 2-3**. The difference in average annual temperature between Lyman Lake and Chelan is 16.0 ºF, which corresponds to a lapse rate of 3.3 ºF per 1,000 feet.

Evapotranspiration
Evapotranspiration (evaporation plus transpiration) accounts for processes that return water on or near the earth's surface back to the atmosphere as water vapor. For the purposes of this study, the term evapotranspiration refers to the return of water to the atmosphere from natural surfaces (i.e. soil, rock, and vegetative surfaces), as well as from transpiration from natural vegetation. Evaporation and transpiration resulting from the irrigation of crops is analyzed in the section on irrigation use. Some factors that control evapotranspiration are the type and density of vegetation, air temperature, wind, timing, duration and type of precipitation, and slope aspect.

If vegetation has unlimited access to soil water, and if the effects of advection and heat storage are ignored, then evapotranspiration will occur at a theoretical rate known as potential evapotranspiration (PET). Because soil moisture is often limited in warm and dry climates, actual evapotranspiration (AET) is typically lower than PET.

Free water evaporation is a term describing the amount of water evaporated from surface water bodies such as lakes, ponds and wetlands. Free water evaporation from major surface water features was estimated in addition to evapotranspiration.

Average annual PET was estimated using a heat-index method (Thornthwaite, 1948). Average temperature and precipitation from Lyman Lake, Stehekin, Holden Village and Chelan were used to estimate PET at these locations, and an empirical equation (Pike, 1964) relating average precipitation to PET was used to estimate AET. The estimated AET values were distributed among sub-basins to assign a value for AET to each sub-basin. The sum of actual evapotranspiration in each precipitation band was used to calculate average values of AET for WRIA 47.

Free water evaporation was estimated using evaporation pan data collected at the Wenatchee Experimental Station (elevation ~875 feet) from 1957 to 1997 (OCS, 2006). Evaporation pan data, from recordings taken during the months of April through October, indicate annual pan evaporation is 40.88 inches. This value was multiplied by a pan coefficient of 0.70 to adjust for excess loss caused by heating of the pan and to incorporate differences in elevation between the Wenatchee Experimental Station and higher elevations in WRIA 47 (there are no pan data available within WRIA 47). The annual free water evaporation from surface water in WRIA 47 is 28.6 inches.

Table 2-5 summarizes the estimates of AET for climate stations within WRIA 47. The average-year evapotranspiration (average annual evapotranspiration) for WRIA 47 ranged from 7.1 inches (Lyman Lake) to 18.6 inches (Holden Village).

AET is limited by available moisture. As precipitation increases, AET approaches PET. The warmer and drier lower elevation sub-basins have a much lower ratio of AET to PET than the upper sub-basins (**Table 2-5**). Increasing seasonal moisture will cause a greater rise in AET for lower-elevation sub-basins than higher-elevation sub-basins. However, the higher elevation sub-basins that experience the most precipitation and cover more of the watershed likely control the total evapotranspiration for the watershed. More than half of WRIA 47 lies above 3,000 feet elevation, and it is probable that the upper basin average AET values are relatively insensitive to changes in precipitation that lie within the typical range of precipitation in these regions of the WRIA 47.

Annual free water evaporation is estimated to be 28.6 inches. This value, applied to the approximately 33,300 acres of Lake Chelan and the 1,000 acres of lakes, ponds and reservoirs in WRIA 47 corresponds to a volume of 80,000 and 2,400 AF of evaporation per year, respectively.

Table 2-5 – Annual Evapotranspiration for Average, Warm, and Cool Years

Station	Elevation (feet)	PET[1] (in/yr)			AET[2] (in/yr)		
		Average	Wet/Cold	Warm/Dry	Average	Wet/Cold	Warm/Dry
Chelan	1,120	27.3	25.5	30.4	10.1	13.6	4.0
Stehekin	1,270	22.3	19.9	27.0	18.6	18.7	16.6
Holden Village	3,220	15.3	15.0	18.1	14.3	14.4	14.4
Lyman Lake SNOTEL	5,980	7.2	7.2	7.2	7.1	7.2	7.1

[1]PET = the amount of water lost to evapotranspiration in an average year given unlimited moisture availability.
[2]AET = the amount of water actually lost to evapotranspiration, limited by moisture availability.

Estimates for evapotranspiration in WRIA 47 are consistent with other published estimates for similar basins in central Washington. Average annual AET values for other areas of central Washington were estimated by the US Geological Survey (USGS; Bauer and Vaccaro, 1990) at approximately 12 inches in upper Naneum Creek (similar to the upper elevations of WRIA 47 above 3,000 feet) and approximately 9 inches in the southern half of Douglas County (similar to the middle elevations of WRIA 47).

The following assumptions were made in estimating evapotranspiration.

- A regional distribution of precipitation, temperature and evapotranspiration values using available data from weather and SNOTEL stations.
- Influence of wind and micro-climates within the basin were insignificant.

2.5 HYDROLOGY

Precipitation that is not lost to evapotranspiration runs off steep slopes into stream channels and minor tributaries of the Stehekin River and Railroad Creek, and into minor tributaries of

Lake Chelan, where they ultimately discharge out of Lake Chelan into Chelan River and finally the Columbia River. The Stehekin River and Railroad Creek are the primary tributaries that discharge into Lake Chelan, which discharges into the Columbia River via the Chelan River. Smaller tributaries include 25-Mile and First Creeks, and Fish, Prince, Gold, and Safety Harbor Creeks (**Figure 2-1**). Minor amounts (less than 5 percent of total WRIA 47 discharge) of stream flow discharges from sub-basins adjacent to the Columbia River.

Data Sources

The USGS maintains two stream gauges in WRIA 47 and historically maintained four other gauges. No long-term stream gauge data are available for Twenty-five Mile, Antoine or First Creeks. **Table 2-6** summarizes the significant data for long-term gauges.

The Phase 1 (RH2, 2008) water quantity study summarized the period of record and location of all available flow data in WRIA 47 and is attached in **Appendix A.**

Table 2-6 – Long-Term Stream Gauge Data

Gauge	USGS Station	Drainage Area (mi^2)	Period of Record	Mean Annual Streamflow (cfs)	Minimum Annual Streamflow (cfs)	Maximum Annual Streamflow (cfs)
Chelan River at Chelan	12452500	924	1903-date	2,055	1170	3140
Stehekin River at Stehekin	12451000	321	1910-1925; 1926-date	1,400	871	2010
Railroad Creek at Lucerne	12451500	64.8	1911-1913; 1927-1957	200	128	297
Safety Harbor Creek near Manson	12451600	7.85	1961-1969	14	7.1	22
Grade Creek near Manson	12451620	8.45	1961-1969	5.6	3.7	8.3
Gold Creek near Manson	12451650	6.3	1961-1969	0.55	0.55	0.45
Antilon Lake Feeder	12451700	-	1958-1969	-	-	-

Figures 2-6 and 2-7 illustrate monthly stream flow for these streams for the period of record (USGS, 2008).

Other watershed flow data were measured infrequently. The Ecology (1989) study included a basin-wide monitoring effort, albeit during a relatively dry year, that was used to create a water balance. Data from this study indicated that the Stehekin River and Railroad Creek contributed 75 percent of inflow to Lake Chelan, and other upper basin tributaries contributed 20 percent of inflow.

A study measured large and smaller streams during April to October of 2000 (Anchor, 2000). These data (**Table 2-7**) show that flows in the smaller tributaries ranged by more than an order of magnitude between minimum and maximum flows during one year. In contrast, the annual flow in Stehekin River and Railroad Creek range within 50 percent of the average over the period of record, shown in **Figure 2-8**.

Table 2-7 – Summary of Stream Flow Data in 2000

Stream	Maximum Peak Flow (cfs)	Date	Base Flow (cfs)	Date (2000)
Stehekin River	6,010	May 22	1,130	Aug 1 – Sept 28
Railroad Creek	1,284	June 15	153	Aug 1 – Sept 28
Prince Creek	531	June 18	26.1	July 1 – Sept 28
Fish Creek	526	June 21	24.6	July 1 – Sept 28
25-mile Creek	145	May 23	8.5	July 1 – Sept 28
Safety Harbor Creek	141	June 8	5.3	July 1 – Sept 28
First Creek	97.8	April 14	7.6	May 15 – Sept 28
Grade Creek	35.8	April 22	2.6	July 1 – Sept 28
Gold Creek	11.1	April 20	0.7	June 1 – Sept 28
Mitchell Creek	6.5	April 31	1.8	May 15 – Sept 28

Lake Chelan Discharge

Nearly the entire outflow from Lake Chelan is diverted through a penstock for hydroelectric power production at the Chelan Falls Power Plant, owned by Chelan PUD. The relatively small dam at the outlet was constructed in 1927, causing the lake to rise by approximately 21 feet. Although Lake Chelan is operated as a storage reservoir for power production, the lake level is generally maintained at full pool during the peak recreational season (June through September). The water level of Lake Chelan can then drop up to 21 feet during the winter before the spring runoff begins. In general, discharge from the lake is held at a constant 2,000 cubic feet per second (cfs). However, during spring runoff the average flow rises to approximately 4,000 cfs, and during dry years the flow can drop to below 200 cfs during late winter. The rate of outflow can also drop during late summer in order to maintain the lake level at a constant elevation for recreational usage. Water that does not go through the power plant flows through a spillway and down the relatively short Chelan River to the Columbia River. Discharge from the power plant flows directly to the Columbia River through a tailrace canal.

Flows recorded at the Chelan River gauging station include the combined discharge from the hydroelectric power plant, the Chelan Dam spillway and irrigation withdrawals from the power plant penstocks. Since nearly all water flows through the power plant, very little or no stream flow in the Chelan River channel exists except during periods of spill. The available data represents discharge from Lake Chelan and not flow in the Chelan River. **Figure 2-9** illustrates the monthly flow from Lake Chelan since the early 1900s. The data illustrate the effect of dam operation since 1927, where constant flows are held during the summer, fewer peaks occur during the spring flood than before dam operation and more frequent low flows occur.

Based on data trends for the Stehekin and Chelan Rivers shown in **Figure 2-8**, average annual flows in Lake Chelan have not changed significantly over the period of gauging, from the early 1900s to date. The graph indicates that, as a percentage of stream flow, the Stehekin River was 65 to 80 percent of Chelan River flow. Low flow years exhibit the highest ratio of Stehekin to Chelan River flows, which suggests that water stored as snow and ice in the Stehekin Sub-basin contributes a higher percentage of total flow during dry years, and that evapotranspiration losses from lower tributaries further reduce stream flow during dry years (see Granshaw, 2002).

Tributary streams to Lake Chelan experience peak runoff during the spring melt in May to July, and low flows during September through February. Water in Lake Chelan is generally stored during the runoff period and released during the low flow season to generate hydroelectric power, resulting in a flattened hydrograph compared to natural flows (**Figures 2-6, 2-7** and **2-8**).

Average annual inflow to Lake Chelan is estimated to be approximately 1.6 million AF, equivalent to a constant flow of approximately 2,200 cfs. The Stehekin River accounts for 65 percent of the total inflow to the lake, Railroad Creek contributes 10 percent and approximately 50 other smaller tributaries contribute another 25 percent of the surface inflow (FERC, 2001). Precipitation that falls directly on the lake contributes 4.4 percent of the total inflow to the lake, or approximately 70,000 AF per year.

Figures 2-10 and **2-11** show water year data for Stehekin River and Lake Chelan discharge representing dry (2001), wet (1972) and average (1984) flows during the previous 30 years of the period of record. The data show that during average years, flow from Lake Chelan is kept near 2,000 cfs. During wet years, surplus water is discharged during the spring and summer runoff season, and during a dry year, Lake Chelan flow is curtailed to replenish storage and manage lake levels.

The smaller perennial streams are often dry in late summer and fall, or even early summer (Antoine Creek). The smaller creeks are susceptible to periodic flooding from springtime rain on snow runoff events and during rare high intensity summer thunderstorms (USFS, 2000).

Reservoirs

There are two reservoirs in WRIA 47 with volumes of 10 AF or greater (smaller private ponds with volumes less than 10 AF were not described in this assessment). Wapato Lake (2,000 AF) and Antilon Lake (1,920 AF) were constructed in natural, in-channel basins enlarged to enhance irrigation storage. Water levels in these reservoirs comprise a total area of approximately 338 acres, with storage of approximately 3,920 AF, including active and inactive reservoirs (Ecology Dam Safety Office, 2006).

Summary

Most of the land in WRIA 47 that contributes runoff to the watershed is under Federal management and land use planning by the USFS and NPS. These manage land use practices that potentially affect the surface water flows into WRIA 47. No significant changes in land use or water use are anticipated in this intensively managed basin that could affect the watershed hydrology. The USGS and Chelan PUD will continue to monitor surface water flows, and the Chelan PUD will continue to use hydrologic data to forecast spring runoff to support the management of lake levels and Chelan River flows under the FERC license. Surface water characteristics of WRIA 47 have remained consistent since dam operation began in 1927.

2.6 GEOLOGY AND GROUNDWATER

Recent hydrogeologic studies of WRIA 47, with emphasis on the Wapato Sub-basin, compiled and contributed new geologic information in three reports: Harper-Owes (1989); Ecology (1995); and Geomatrix (2006). These reports, drillers logs compiled by Ecology and geologic mapping by Tabor et al. (1987) provide the background for the following summary of hydrogeologic and groundwater characteristics of WRIA 47. **Figures 2-12** and **2-13** present geologic maps of WRIA 47 and the Wapato Main Stem and Manson Lakes Sub-basins, respectively, using data compiled from the Washington State Department of Natural Resources (WDNR).

Geologic Characteristics

Geologic Units

Three distinct geologic groups occur in WRIA 47 that record the complex geologic history of extensive regional geologic processes that formed the bedrock foundation of the watershed and the relatively recent glacial and post-glacial processes that modified and deposited unconsolidated sediment upon the bedrock. Bedrock comprises much of the exposed surficial geologic units in the watershed on the steeper slopes above terraces and hills of the lower basin, and forming the slopes and ridges of the upper basin above 1,600 feet. Glacial episodes deposited relatively broad layers of fine to coarse-grained sediment in the valley floors and partially on the valley sidewalls or in patches on ridges. Lakeshore, river and landslide deposits are found primarily along river and creek bottoms and at the base of slopes. The glacial and post-glacial deposits contain most of the available groundwater in WRIA 47, and nearly all developed and irrigated lands are underlain by unconsolidated units. The unconsolidated deposits are found primarily as discontinuous layers of sediment in the Wapato Main Stem and Manson Lakes Sub-basins, as terrace and flood deposits in the Antoine Creek and Howard Flats Sub-basins, and locally as alluvial fill in the valley bottoms of other sub-basins.

The following broadly summarizes the general geologic conditions in WRIA 47. The sources described above provide detailed descriptions and delineations of individual geologic formations.

Bedrock

The oldest geologic units exposed at the surface of WRIA 47 consist primarily of Late Cretaceous age igneous tonalities and metamorphic migmatites and gneiss of the Chelan Complex (Hopson and Mattinson; 1971; Tabor et al, 1987). These erosion-resistant units are composed of common rock-forming minerals in dense, crystalline form, which are weathered into tan and gray fractured outcrops that are white to dark gray and less fractured in the subsurface. Bedrock units outcrop on the surface generally above elevations of 1,600 feet.

Glacial Deposits

Glacial processes eroded the U-shaped valley of Lake Chelan and its primary tributaries. The advance and retreat of glacial ice coincided with the deposit of fine to coarse-grained sediment ahead of or beneath glacial ice. Outflow channels from the ice front discharged coarse-grained outwash channels in broad valleys; the outwash deposits are interbedded with finer-grained sediment resulting in compositionally variable and stratified sand, gravel and silt. Some of these former glacial outwash channels were subsequently abandoned as ice melted, resulting in terraces of sand and gravel along slopes above the axis of the Lake Chelan and Columbia River Valleys. Coarse-grained deposits are typically found at elevations between 1,300 and 1,500 feet.

Formation of ice dams across outflow channels and at the terminus of Lake Chelan resulted in temporary lakes that were subsequently filled with silt. If over-ridden by glaciers, these silt layers are hard and dense, whereas lake deposits accumulated ahead of glacial ice are typically platy and soft. Silt deposits are typically found directly overlying bedrock in lower elevations of the basin, generally below elevations of 1,400 feet along the Lake Chelan shoreline in the Wapato Main Stem Sub-basin (Ecology, 1989).

Glacial ice plucked and carried rock debris in a layer of plastic sediment beneath the ice that was subsequently pulverized into silt-sized particles. The sediment was over-ridden, pulverized, and compressed by the ice into dense, glacial till; sediment that was pushed aside or carried on top of the ice became loose glacial moraine or ice-contact deposits. Both till and moraine sediment is comprised of widely-variable grain sizes ranging from silt to boulders. Till deposits are typically less than 10 feet thick, and found below elevations of 1,500 feet in the Wapato Main Stem and Manson Lakes Sub-basins. Till is also present in the upper elevations of the watershed and deposited by more recent alpine glacial activity.

Glacial deposits outcrop typically below elevations of 1,600 feet and consist of relatively thick layers that filled larger depressions of eroded bedrock or thin layers overlying bedrock ridges.

Turbulent events continued to substantially modify the terrain of WRIA 47 preceding and during Quaternary Age glaciations (approximately 12,000 to 18,000 years ago). Catastrophic release of water behind ice dams in northern Washington and Montana flooded the Columbia Basin, scoured channels down to basalt bedrock and deposited extensive layers of coarse to fine-grained sediment along the scoured channels. These glacial flood units primarily occur in the sub-basins adjacent to the Columbia River and within 1 mile of the Columbia River in WRIA 47, and consist of tens to several hundred feet thick layers of sand, silt and gravel.

Post-Glacial Deposits
Final glacial retreat allowed river, shoreline and mass-wasting processes to rework the glacial deposits and further erode bedrock. These processes resulted in deposits of sand and gravel alluvium along river and creek bottoms, broad terraces above lake shorelines and fans of landslide debris, a jumbled mixture of bedrock blocks in a matrix of sand, silt and clay at the base of steep slopes. Thin and discontinuous layers of coarse to fine-grained alluvium lie along and beneath all stream channels in WRIA 47. The alluvial deposits are typically less than 100 feet thick and vary widely in composition from thin silt lenses to thick gravel layers. Steep slopes remain susceptible to release of small to large landslides that discharge onto flat benches or stream channels.

Hydrogeologic Characteristics

Bedrock Units

Bedrock units contain little primary porosity within rock fractures that store small quantities of groundwater. Locally, wider fractures and voids may create additional groundwater storage volume. Fracture orientation or density, however, is generally an inconsistent indicator of groundwater availability or flow and prediction of groundwater occurrence in bedrock is inconsistent. Experienced local drillers favor groundwater exploration on ridges and knobs, where greater fracture density and groundwater storage are generally encountered.

Depth to groundwater in bedrock units varies widely, from tens to several hundreds of feet. Groundwater levels in bedrock wells completed deeper than 150 feet typically rise to within 50 to 100 feet of ground surface, indicating confined conditions that pressurize the groundwater within fractures. Groundwater levels in bedrock wells tend to remain constant through the year, indicating their slow rates and widespread sources of recharge. Groundwater in the bedrock is replenished by slow percolation of rainwater through fractures at the surface or indirectly via recharge through overlying unconsolidated units. The degree of hydraulic continuity between bedrock and surface water varies widely along the Lake Chelan shoreline, where water levels may or may not coincide even within wells that are less than 100 feet from the shoreline.

Surficial Aquifer

The surficial aquifer comprises the groundwater-saturated portions of coarse-grained glacial outwash units and post-glacial alluvium and terrace deposits that consist of dense to loose sand and gravel layers in thicknesses of tens to 300 feet. The aquifer comprises the greatest volume and source of groundwater available for withdrawal. The surficial aquifer is discontinuously distributed in the Wapato Main Stem and Manson Lakes Sub-basins, underlies the valley floors in creeks and coulees, and forms the base of the Howard Flats and Antoine Creek sub-basins. Thick sequences that include overlying glacial flood deposits may attain 300 feet below Howard Flats.

The limited extent and thickness of the surficial aquifer also localizes the availability of groundwater in WRIA 47. However, high permeability zones of the surficial aquifer in certain areas may promote high rates of precipitation and irrigation recharge which becomes available for local sources of groundwater withdrawal.

Groundwater levels in the surficial aquifer vary from near surface to more than 100 feet according to patterns of recharge and the distribution and thickness of lower permeability lacustrine and till layers or bedrock that impede groundwater flow into and within the surficial aquifer.

Fine-grained units consisting of till and lacustrine deposits are interbedded with, overlie and form lateral boundaries with the surficial aquifer. These layers are not sources of groundwater to WRIA 47, but rather impede flow between units and act as barriers to recharge in the surficial aquifer.

Glacial Flood Units

The glacial flood units are found in the sub-basins adjacent to the Columbia River and the Howard Flats and Antoine Creek Sub-basins. Groundwater occurs extensively in the glacial flood units generally at depths less than 100 feet and within moderate to high permeability coarse sand and gravel layers interbedded with very low permeability silt units. The silt layers isolate and impede groundwater flow, whereas high permeability layers yield significant flow to wells in the range of tens to hundreds or even thousands of gallons per minute (gpm). The glacial flood units are in significant hydraulic continuity with the Columbia River within several thousand feet of the river. The flood deposits are recharged by precipitation, lateral discharge from adjacent units (and the Columbia River), and percolation of return flow from irrigation water and domestic wastewater. The flood units exhibit the highest permeability of any units in the watershed; consequently, these units provide the most significant source of groundwater in WRIA 47 and are tapped for domestic, irrigation and municipal withdrawals, including the Chelan Falls Water System and Chelan PUD wells for the Chelan Falls Hatchery.

Hydrologic Cycle of WRIA 47

Groundwater in WRIA 47 is replenished from precipitation falling in the basin and infiltrating into porous surficial deposits. The broader and hilly terrain of the lower watershed sub-basins promotes groundwater recharge. In contrast, steep, thinly covered bedrock areas promote runoff and little recharge into bedrock fractures. Groundwater is recharged artificially via seepage from irrigation drains, via return flow infiltrating from irrigated lands, and via seepage from Wapato, Roses and Dry Lakes in the Manson Lakes Sub-basin. Groundwater elevations and yield to wells in these areas are expected to be artificially high relative to non-irrigation conditions.

Precipitation and irrigation return flow that enters the subsurface below the root zone migrates with groundwater along flow paths of greatest permeability and gradient. The underlying bedrock topography and its mantle of low permeability glacial deposits control groundwater flow paths in the lower elevation sub-basins. Valley bottoms in the upper elevation sub-basins are comprised of alluvium and glacial deposits that contain groundwater in continuity with streams. Groundwater flow is constrained to these narrow alluvial aquifers by underlying bedrock. Streams in the lower elevation sub-basins have incised unconsolidated units and may exchange groundwater with underlying aquifers. The streams in the upper elevations of the sub-basins are likely losing streams, where surface water tends to seep out of the streams into underlying aquifers, promoting groundwater recharge. In the lower basins, the streams are likely gaining, where groundwater from adjacent aquifers seeps into the stream, promoting base flow. Seepage into streams is likely greater near areas of irrigation water storage, conveyance and application where irrigation return flow that infiltrated to the surficial aquifer discharges into streams.

Groundwater Elevations and Flow

Widely variable conditions affect groundwater elevations, and include seasonal and long-term precipitation trends, topography, subsurface layering and geologic unit composition. The limited groundwater elevation data from existing wells somewhat reduce the accurate determination of the elevation, flow directions or velocity of groundwater within the watershed. Groundwater withdrawals will locally affect groundwater levels, but not enough to alter local groundwater flow directions. Ecology (1989) provided generalize groundwater flow maps that illustrate the generalized pathways of groundwater through the surficial aquifer. These maps are reproduced in **Appendix B**.

Hydraulic Boundary between WRIA 47 and Columbia River

Within approximately ½-mile of the Columbia River, the groundwater flow directions and hydraulic gradient of the hydrogeologic units are potentially controlled by the river stage. This effect increases with proximity to the river. The Chelan Falls area experiences the greatest river influence, where portions of the permeable flood deposits are in hydraulic continuity with the river. The river also has some influence on groundwater elevations along the shoreline at the Howard Flats and Antoine Creek Sub-basins. Therefore, the degree of hydraulic continuity between the river and geologic units and the hydraulic boundary of WRIA 47, is indefinite. This boundary is a significant characteristic of the watershed and could be determined by accurate mapping of groundwater elevations in existing wells. Boundary delineation would support water balance estimates, determining the potential availability of groundwater in the watershed and identifying hydraulic continuity between groundwater and the river to identify areas of sustainable yield, and would be required for establishing impacts of groundwater withdrawal on instream flow.

The Physical Availability of Groundwater in WRIA 47

Figures 2-12 and 2-13 show the distribution of domestic, municipal and irrigation wells recorded by Ecology for WRIA 47. The map illustrates areas of the highest density of groundwater withdrawal, which generally indicates the availability of groundwater in the watershed. Groundwater withdrawal primarily occurs at exempt wells to supply single residence domestic use. Public supply wells (Chelan Falls Water System, Chelan PUD) and some private irrigation wells derive groundwater from flood deposits in hydraulic continuity with the Columbia River.

Groundwater in bedrock generally occurs in isolated, discontinuous, open fractures that yield small quantities of water to single residence domestic wells. Although groundwater is widespread in bedrock, the amount of available groundwater at any one location is unpredictable, and potentially in quantities that cannot continuously sustain withdrawals.

The groundwater development potential of the bedrock unit is limited to wells that yield less than 10 gpm and more typically 2 to 4 gpm.

Yield to domestic wells in the surficial aquifer range from 10 to 100 gpm, but because of their limited size, are not considered significant sources of groundwater for uses other than single residence domestic supply, small irrigation projects and a few smaller public (Group B) systems.

Groundwater sources within flood deposits and in hydraulic continuity with the Columbia River may potentially yield 1,000 gpm or more to wells.

Table 2-8 summarizes the groundwater development potential from different hydrogeologic units in WRIA 47.

Table 2-8 – Groundwater Development Potential in WRIA 47

Hydrogeologic Unit	Sub-basins	Well Yield
Flood Units	Howard Flats, Antoine, Columbia River	100 to 1,000+ gpm
Surficial Aquifer	Wapato Main Stem, Manson Lakes, Antoine and Howard Flats at > 0.5 mile from Columbia River; valley bottoms in upper elevation sub-basins	10 to 100 gpm
Bedrock	Upper elevation sub-basins	2 to 10 gpm

Groundwater Recharge

Groundwater recharge is precipitation that infiltrates below the root zone in soil and is not lost to evapotranspiration or as runoff to surface water. Some of the recharge migrates in shallow soil aquifers and rapidly discharges to surface water where groundwater tables intersect a low-lying land surface (for example, at springs along steep slopes within stream channels or below cliffs), and a minor portion will be withdrawn by supply wells. However, much of the infiltrated precipitation enters the surficial or bedrock aquifers, migrates down gradient through adjacent geologic units, and ultimately discharges into Lake Chelan or the Columbia River.

Surface water in steep gradient streams will recharge the surficial aquifer where it abuts the mountain or hillside slope. This mountain front recharge is a significant source of groundwater recharge for the surficial aquifer and valley bottom aquifers, particularly in the lower elevation sub-basins that experience high evapotranspiration rates such as in the gulches of Manson Lakes and the sub-basins adjacent to the Columbia River. The recharge from winter storms and spring runoff discharges back into the lower reaches of streams as summer and fall base flow.

Irrigated lands receive additional recharge at rates of 10 to 40 percent of the application rate (Geomatrix, 2006). Consequently, groundwater levels are typically higher and groundwater is more readily available for withdrawal in irrigated areas, in particular, the Manson Lakes Sub-basin. Some of the groundwater discharges back into the nearby lakes or drains.

Recharge is largely controlled by the capacity of earth material (soil type and underlying geologic structures) to absorb and facilitate the downward migration of water. For example, fine-grained soils derived from till and other fine-grained glacial deposits usually have low permeability and slower recharge rates.

Several studies have estimated groundwater recharge and discharge from the surficial aquifer in the Wapato Main Stem and Manson Lakes Sub-basins using theoretical methods to calculate groundwater flow, measurements of base flow, and estimates of irrigation return flow. These estimates range from 160 to 160,000 acre-feet per year (AFY) and are likely closer to 10,000 AFY (Ecology, 1989; Ecology, 2005; Geomatrix, 2006).

Recharge has been simulated in various parts of eastern Washington by Bauer and Vaccaro (1990) using the USGS Deep Percolation Model (DPM). They estimated recharge in the Columbia Basin and Waterville Plateau to be about 1 inch per year, or approximately 10 percent of the annual rainfall in these areas. Because climate and geology in the lower elevations of WRIA 47 are similar to the Columbia Basin, this value was chosen to represent the lower recharge limit in WRIA 47. A simple average of the upper and lower recharge limits was used to establish a value for average annual recharge.

Recharge in WRIA 47 is controlled by the permeability of soil and underlying geologic units. Recharge is limited in areas of bedrock that can receive water directly from precipitation or overlying soil and thin geologic units. Recharge is greatest where porous and permeable coarse-grained glacial deposits and alluvial deposits occur at the surface, primarily in the Wapato Main Stem and Manson Lakes Sub-basins (**Figure 2-13**). Annual recharge in the basin likely ranges from 1 to 24 inches, or 33 percent of average annual precipitation, based on the differences between precipitation and evapotranspiration and the permeability. Variations in recharge during dry and wet years were not examined due to the extreme range already present in annual average estimates.

Summary

The geologic characteristics of WRIA 47 control the rate of runoff from higher elevation sub-basins underlain by bedrock and the rate of groundwater recharge in lower elevation sub-basins underlain by unconsolidated glacial and post-glacial deposits. The amount of groundwater recharge returning to Lake Chelan is highly variable, but appears to be a minor component of the overall lake water balance. However, extensive water use in the lower elevation sub-basins alters the natural hydrologic cycle in these sub-basins, so that surface water applied for irrigation artificially recharges groundwater which in turn affects base flow in drains and creeks. Agricultural practices and domestic land use may introduce man-made chemicals into groundwater that may convey these chemicals along groundwater flow paths to surface water. Future changes in land use could affect the location, type and rates of recharge that will affect both water quantity and quality in the lower elevation sub-basins. Watershed planning should focus on the areas where potential recharge are greatest, that is, in areas underlain by coarse-grained glacial and post-glacial deposits.

Section 3 – Existing Water Rights and Claims

3.0 BACKGROUND

In order to understand the implications of the following discussion about water rights and claims in WRIA 47, it is important to understand the basics of both water rights and claims. The following is an excerpt from the Department of Ecology (Ecology) website (underlines added by author).

> The waters of Washington State collectively belong to the public and cannot be owned by any one individual or group. Instead, individuals or groups may be granted rights to use them. A water right is a legal authorization to use a predefined quantity of public water for a designated purpose. This purpose must qualify as a beneficial use. Beneficial use involves the application of a reasonable quantity of water to a non-wasteful use, such as irrigation, domestic water supply, or power generation, to name a few.
>
> State law requires certain users of public waters to receive approval from the state prior to using water - in the form of a water right permit or certificate. Any use of surface water (lakes, ponds, rivers, streams, or springs) which began after the state water code was enacted in 1917 requires a water-right permit or certificate.
>
> Likewise, withdrawals of underground (ground) water from 1945 onward, when the state groundwater code was enacted, require a water right permit or certificate – unless the use is specifically exempt from state permitting requirements. While "exempt" groundwater uses are excused from needing a state permit, they still are considered to be water rights.
>
> In the 1960's, the Washington State legislature realized the need to document water rights established prior to 1917 for surface water and prior to 1945 for groundwater. These water rights are *vested rights*. A vested right is a water right established through beneficial use of water. A water right claim is a statement of beneficial use of water that began prior to 1917 for surface water and prior to 1945 for groundwater. In 1967, the Claims Registration Act was enacted to record the amount and location of these vested water rights.
>
> The Claims Registration Act set a specific time window for water users to file their water right claims with the state. Users of exempt ground-water withdrawals were also encouraged to file claims so that they could establish priority dates for their rights. Some users were not required to file a claim, including:
>
> - Individuals served water through a company, district, public or municipal corporation (the water supplier should have filed claims for its users);
> - Persons with a valid Water Right Permit or recorded Certificate;
> - Individuals with a water right determined by Court Decree and recorded through issuance of a Certificate of Water Right by Ecology or one of its predecessor agencies;
> - Non-consumptive water uses, like boating, swimming, or other recreational and aesthetic uses, with no physical diversion or artificial impoundment of water; or
> - Owners of livestock that drink directly from a surface-water source.

The initial statewide opening of the Claims Registry ended June 30, 1974. The legislature has subsequently re-opened the Claims Registry three times. The most recent opening occurred from September 1997 to June 1998. Statewide, there are roughly 169,000 water-right claims on record.

Claims will remain valid until water rights adjudication occurs, whereby the validity of the claims must be proven before a court of law. Adjudication can be initiated by several means, but normally will not occur unless there are significant problems with water availability in an area. During adjudication, claimants are required to prove that water has been in constant beneficial use prior to 1917 for surface water and prior to 1945 for groundwater. Five or more consecutive years of non-use may invalidate a claim.

3.1 SURFACE AND GROUNDWATER RIGHTS AND CLAIMS IN WRIA 47

Table 3-1 summarizes surface water and groundwater rights and claims in the Twenty-five Mile Creek, Antoine Creek, First Creek, Howard Flats, Manson Lakes and Wapato Main Stem Sub-basins. **Table 3-1** presents the total rights and claims for the entire WRIA 47 area. These summaries were derived from Ecology's water rights data base.

Ecology's Geographic Water-right Information System (GWIS) database is the source of information for the tables, figures and summary presented here. The GWIS is a graphic component of the Water Right Tracking System (WRTS). The GWIS allows users to separate water use by location.

Ecology separates the water rights holders contained within the GWIS into two categories: Claim Place of Use (CPOU) and Place of Use (POU).

The CPOU water rights records are for water uses that are claimed to have been exercised before the water permitting system (1917 for surface water and 1945 for groundwater). These claimed rights have not been validated by the State and require judicial processing through what is known as a general adjudication of water right to either validate or invalidate the claimed rights. The result of a general adjudication is the issuance of adjudicated certificates of water right for those rights that are validated. Quantities posted on claims are frequently inaccurate or exaggerated, and therefore unreliable sources of information supporting water use in the watershed. For example, some claim quantities apparently exceed the entire flow of the Chelan River, likely due to a transcription error indicating a quantity in units of cfs rather than the intended quantity in gpm, quantities in gpm, rather than the intended gallons per day.

The POU water rights records relate to those water uses that were initiated after the water permitting system had been established. These records include water right applications, permits and certificates. An application for a water right, although in the POU records, does not constitute a "water right" because it does not authorize the use of water. It is merely a request that the State authorize the use of water for an identified purpose. A permit grants permission to put water to a beneficial use subject to the terms and conditions of that permit. Once the water is put to beneficial use, the water right is said to be "perfected" and a water right certificate is granted. At this point, the water is attached to the land and remains within the land unless specifically severed as part of a transaction.

Ecology's GIS database for water right places of use identifies 1,131 water rights records (including claims) in the WRIA 47 study area. The 1,131 total records consist of 919 surface water rights and 212 groundwater rights, as well as 442 water right claims consisting of 329 surface water claims and 113 groundwater claims.

In addition, Ecology records indicate three pending water rights applications for new appropriations of water and five pending change applications for existing rights. There are a total of 120 permits (water rights that have not yet been fully perfected and issued a water right certificate), 47 adjudicated certificates of water right (the result of previous water right adjudications in a superior court), 483 water right certificates, 7 change certificates (where specific details of an existing water right have been changed), 22 change Reports of Exam (where changes to an existing right have been approved but have not yet been fully perfected and a change certificate has not yet been issued) and two temporary permits for use of water.

Neither instantaneous (gallons per minute or cubic feet per second) nor annual quantities (AFY) of water are allowed to be increased through the water right change process, and in some cases, they may be reduced in situations where the full quantities of water have not been historically put to use. Changes can be made to permits, certificates, adjudicated certificates or claims. These changes are most commonly a change in type of use, location of the point of diversion or withdrawal, number of points of diversion or withdrawal, and/or place of use.

Table 3-1 WRIA 47 GWIS Water Rights/Claims Summary

		CFS	GPM	Annual Quantity (total) AFY	Acres irrigated	# of Rights/ Claims	Surface	Ground
25-mile Creek								
	CPOU[1]	NA	NA	42	5	17	17	0
	POU[1]	10.1	45	356	354	39	37	2
	sum	**10.1**	**45**	**398**	**359**	**56**	**54**	**2**
Antoine Creek								
	CPOU	NA	NA	67	20	3	3	0
	POU	5.8	1,963	1,779	651	47	27	20
	sum	**5.8**	**1,963**	**1,846**	**671**	**50**	**30**	**20**
First Creek								
	CPOU	NA	NA	1,514	670	15	12	3
	POU	5.2	0.0	117	22	5	5	0
	sum	**5.2**	**0.0**	**1,631**	**692**	**20**	**17**	**3**
Howard Flats								
	CPOU	NA	NA	782	203	21	9	12
	POU	1.0	13,140	6,457	1,573	36	12[4]	24[3]
	sum	**1.0**	**13,140**	**7,239**	**1,776**	**57**	**21**	**36**
Manson Lakes								
	CPOU	NA	NA	2,591	806	71	33	38
	POU	57.5	1,149	12,215[5]	3,457	61	43	18
	Sum	**57.5**	**1,149**	**14,806**	**4,263**	**132**	**76**	**56**

Table 3-1 WRIA 47 GWIS Water Rights/Claims Summary (continued)

		CFS	GPM	Annual Quantity (total) AFY	Acres irrigated	# of Rights/Claims	Surface	Ground
Wapato Main Stem								
	CPOU	NA	NA	6,609	1,774	315	255	60
	POU	156 4,209[2]	1,000	24,732[5] 640,000[2]	5,338	480	448[4]	32[4]
	sum	**365**	**1,000**	**31,341**	**7,112**	**795**	**703**	**92**
Direct Drainage to Columbia River								
	CPOU	1	10,896	2,658	477	24	13	11
	POU	431	57,515	345,611	1,853	74	41	33
	Sum	**432**	**68,411**	**348,269**	**2,330**	**98**	**54**	**44**
Lucerne Main Stem								
	CPOU	8,493	96	4,699	245	148	138	10
	POU	4	35	443	138	73	71	2
	Sum	**8,497**	**131**	**5,142**	**383**	**221**	**209**	**12**
Railroad Creek								
	CPOU	-	-	-	-	-	-	-
	POU	16	-	59	5.0	6	6	0
	Sum	**16**	**-**	**59**	**5.0**	**6**	**6**	**0**
Stehekin								
	CPOU	111	242	926	163	33	21	12
	POU	29	33	243	85	23	20	3
	Sum	**140**	**275**	**1,169**	**248**	**56**	**41**	**15**
TOTAL		**9,530**	**86,114**	**411,900**	**12,502**	**1,011**	**763**	**248**

[1] CPOU refers to Claim place of use. POU refers to water right permit or certificate place of use.
[2] 4,000 cfs and 640,000AF non-consumptive reservoir/hydroelectric use.
[3] Most points of withdrawal lie within an aquifer in hydraulic continuity with Columbia River.
[4] Several points of withdrawal lie within an aquifer/surface water in hydraulic continuity with Columbia River.
[5] Lake Chelan Reclamation District rights derive from Lake Chelan and applied to both Manson Lakes and Wapato Main Stem Sub-basins.
NA – Data are not sufficiently accurate to quantify
Note: Uses include domestic general, domestic multiple, domestic single, domestic municipal, irrigation, fire protection, power, stock watering and wildlife propagation and are included on individual water rights and claims in various combinations.

The preceding table is a summary of the Department of Ecology Water Rights Tracking System, which includes detailed water rights records. The table lists all of the recorded water rights and claims in WRIA 47 by sub-basin and shows the type of point of withdrawal (headworks gravity flow, surface water pump [surface water], wells [groundwater]), and the Township, Range, and Section associated with the point of withdrawal for each of the water rights and claims.

Figure 3-1 shows surface water rights and claims in the Antoine Creek Sub-basin.

Figure 3-2 shows surface water rights and claims in the Direct Drainage to Columbia River.

Figure 3-3 shows surface and groundwater rights and claims in the First Creek Sub-basin.

Figure 3-4 shows surface and groundwater rights and claims in the Howard Flats Sub-basin.

Figure 3-5 shows surface and groundwater rights and claims in the Lucerne Main Stem Sub-basin.

Figure 3-6 shows surface and groundwater rights and claims in the Manson Lakes Sub-basin.

Figure 3-7 shows surface and groundwater rights and claims in the Railroad Creek Sub-basin.

Figure 3-8 shows surface and groundwater rights and claims in the Stehekin Sub-basin.

Figure 3-9 shows surface and groundwater rights and claims in the Twenty-five Mile Creek Sub-basin.

Figure 3-10 shows surface and groundwater rights and claims in the Wapato Main Stem Sub-basin.

Current Water Use

Also, note that there are numerous areas where water right places of use and water right claim places of use appear to overlap. This is consistent with the findings described below under the discussion of ground and surface water claims.

<u>3.1.1 Water Right Claim in WRIA 47</u>

There is a total of 442 water right claims in WRIA 47. Of this total, 329 are for surface water uses and 113 are for groundwater uses.

<u>3.1.2 Groundwater Claims in WRIA 47</u>

Groundwater uses that began prior to 1945 and for which claims have been submitted may be valid.

Of the 113 groundwater claims, 79 include domestic use as the first use listed and 43 of these claims are solely for domestic use. There are a total of 16 for the sole purpose of irrigation, but many of the claims list irrigation as one of the uses. Most of the claims that include domestic use are likely for residences with a relatively small irrigation component, and essentially wells allowed by the "exempt well" statute, which allows use of a well up to 5,000 gallons per day and up to half an acre of non-commercial lawn and garden irrigation without obtaining a water right from the state. (See the discussion of exempt wells below.)

The water balance has attempted to estimate the number of residences that are relying on individual wells for their water supply and has assumed a daily water use of two values. One was captured by taking the average per capita consumption evident in the City of Chelan from 2004-2007, 215 gallons/person. The other value, 350 gallons per day per residence is the value proposed by DOH ODW *Water System Design Manual*. Any additional assignment of water use to the existing claims would likely result in double-counting of most of these uses.

<u>3.1.3 Surface Water Claims in WRIA 47</u>

Of the 329 surface water claims, approximately 296 include a domestic component, 18 are for irrigation only and 13 are for stock water only. Most of the claims list more than one use, so an exact accounting of the numbers in each purpose is difficult.

If the Planning Unit desires additional details on the land and water use associated with water right claims in WRIA 47, they may wish to consider including a recommendation in the watershed plan for further work to refine these numbers. However, it should be noted that such a detailed analysis is time consuming, would provide detail on what appears to be a relatively minor water use, and would still be uncertain given that adjudication of water rights is the only way to achieve certainty with respect to water right claims. It may be appropriate to address this piecemeal by sub-basin in order of priority.

A general note about the analysis of water right claims.

The data on a water right claim was provided by the claimant. In many cases, that person was not well acquainted with water resources management or water law and, as a result, much of the information on the claims is not accurate. This is especially true where the claimed instantaneous and annual quantities of water are listed. For example, the total number of acres claimed for irrigation in WRIA 47 is 3,478 acres. The total volume of claimed water is 111,605 acre-feet, or 32.1 AF of water per acre. Actual water use is more likely to be 2 to 4 acre-feet of water per acre. Therefore, the claims in the claims register may or may not represent a valid vested water right. However, if they do, the quantities of water listed on the claim are often inaccurate and should not be relied upon for any work related to the water balance for a given area.

3.1.4 Water Rights Adjudications

A general adjudication is a legal process conducted through a superior court to determine the extent and validity of all the existing water rights within a particular water system. A general adjudication can determine rights to surface water, groundwater or both. It does not create new water rights, it only confirms existing rights.

Adjudications provide the only legal means for certainty, clarity and surety for water rights holders, Ecology and others interested in water rights. When the court confirms a water right, that right becomes enforceable against other water users and can be protected from impairment by illegal users or new water rights applications. Adjudicated rights favor senior water rights holders during times of limited water availability. The adjudication process provides Ecology with information necessary for decision-making regarding the impact of granting new rights and proposed changes to existing rights.

The 1917 surface water code established the system of appropriative rights in Washington State, i.e. the system of water rights permits and certificates. However, before 1917, the State also recognized riparian rights. Riparian rights attach only to land bordering a stream or water body. Owners of more distant land could not obtain riparian rights for their land.

> There is no priority of right between riparian owners. All riparian owners have equal rights with competing interests to be resolved by the Courts. As demand increased, the riparian doctrine was divided into (a) the natural flow theory and (b) the reasonable use theory.
>
> Under the natural flow theory, the riparian owner could divert water for domestic purposes that included family, livestock, and gardening, and otherwise had the right to have the water in the stream or lake kept at its "natural flow" level. Under the reasonable use theory, the use of the stream is limited to what is reasonable, having due regard for the rights of others on the water source. (Pharris, 2002)

A subsequent Washington State Supreme Court decision ruled that riparian rights, not beneficially used by 1932 were invalid. (See Department of Ecology v. Abbott, 103 Wash.2d 686, 694 P.2d 1071 (1985)).

Ecology records indicate that four adjudications have been completed in portions of WRIA 47. These areas are: Antoine Creek; Joe Creek; Safety Harbor Creek; and Johnson Creek. These adjudications examined and validated existing surface water rights, including active pre-1917 vested and riparian rights, and active post-1917 State-issued permits or certificates. Except for riparian rights, any post-1917 use of surface water should have applied for a water right permit from the State. Since 1932, all uses of surface water should have applied for a water right permit from the State. Similarly, all groundwater uses initiated after 1944 (except those with a so-called exempt well) should also have applied for a water right permit from the State. If an application was approved, a permit would have been issued and, once the use was perfected, a certificate would have been issued. If the application was denied, no water use should have occurred.

If a vested right or a riparian right was found to exist in the adjudication, an adjudicated certificate of water right would have been issued. Any surface water rights issued by the State subsequent to 1917 and found to be still valid would also have been issued an adjudicated certificate of water right. Similarly, any groundwater rights issued by the State subsequent to 1944 and found to be still valid would also have been issued an adjudicated certificate of water right. Therefore, any water right claims for a right, other than a riparian right, that claim a date of first use after 1917 for surface water or after 1944 for groundwater are likely invalid because they were filed for a use that began after the water codes were enacted and should have already had a water right associated with them.

In some cases, people misunderstood the water right claims process and filed claims for uses for which they already had a water right. In such cases, the right is still valid (assuming water is still being used, etc.) and the claim is redundant. For these and other reasons, including transcription errors, the surface water claims are not being specifically factored into the water balance analysis for WRIA 47.

3.2 EXEMPT WELLS AND WELL LOGS IN WRIA 47

There are four types of groundwater uses exempt from state water right permitting requirements.

- Providing water for livestock (no volume or acreage restriction).
- Watering a non-commercial lawn or garden ½-acre in size or less (no volume limit).
- Providing water for a single home or groups of homes (limited to 5,000 gallons per day).
- Providing water for industrial purposes, including irrigation (limited to 5,000 gallons per day with no acre limit).

These uses are exempt from permitting and establish a water right by putting water to a beneficial use. The priority date for such rights is the date the water was first put to use. In the event of an adjudication of groundwater, any uses that meet the exemption criteria above and for which use can be documented with pumping and drilling records, receipts, etc., would be granted an adjudicated groundwater right for the quantity of water actually put to beneficial use, not to exceed the 5,000 gallon per day limit where it applies. (See RCW 90.44.050). Note that, during adjudication, claimants are required to prove that water has been in constant beneficial use prior to 1917 for surface water and prior to 1945 for groundwater. Five or more consecutive years of non-use may invalidate a claim.

As noted in the discussion of groundwater claims, most of the claims include domestic as one of the stated water uses. It is very likely that a large number of the claims were filed on wells that are exempt from permitting. Claims for groundwater from wells drilled before 1945, which are still active, may be valid. However, the practical reality is that a claim for domestic use is inconsequential because such wells are considered a legal source of water upon the date of first use and are only exempt from the permitting process. The only difference would be that pre-1945 wells, with valid claims, would be found to have an earlier date of priority, which is significant only when periods of water shortage lead to regulation based on seniority (first-in-time, first-in-right). While interruptible rights are regulated fairly often, the regulation of domestic water rights has rarely, if ever, occurred.

Submittal of well logs before 1971 was voluntary. In 1992, well drillers were required to submit notices of intent to construct a water well (also called "start cards") and Ecology's monitoring increased. As a result, the database is quite complete for wells drilled since 1992, incomplete for the period from 1971 to 1992, and scattered for pre-1971. Ecology estimates that the well log database includes about 70 percent of the wells drilled prior to 1991.

Review of well logs reported for WRIA 47 to Ecology was part of the technical assessment work. Well logs submitted by well drillers contain limited to extensive information, including location (often to the nearest ¼, ¼ section), boring and casing diameter, well depth, well construction and testing details (casing type, screen type, pump elevation, yield, drawdown, etc.), and geologic materials encountered at different depths. Ecology's database contains approximately 2,600 well logs for WRIA 47, but many of these are monitoring or resource protection wells and are not used for obtaining water supplies. This study estimates that there are approximately 959 exempt wells in WRIA 47. Water use from these wells was estimated as part of the water budget and is discussed in Section 4 in this Assessment.

Section 4 – Estimated Current Water Use

4.0 DRINKING WATER SOURCES AND DOMESTIC WATER USE

The Washington State Department of Health (DOH) defines Group A public water systems as those regularly serving 15 or more residential connections, or 25 or more people for 60 days during the year. Group B public water systems supply 2 to 14 connections having fewer than 25 people. These water systems are subject to state and local ordinances governing water quality and system operations. The DOH is the primary agency for water system regulation and the Washington State Department of Ecology (Ecology) is the primary agency for water rights regulation. Exempt wells are generally not subject to regulation by DOH or Ecology.

Method

The number of connections and the population served by Group A and Group B public water systems in Water Resource Inventory Area 47 (WRIA 47) were estimated from information obtained through the DOH website, City of Chelan, Lake Chelan Reclamation District and Chelan County PUD No. 1. The total number of residences in the watershed in 2008 was estimated to be 13,211 from current population as provided by the City of Chelan and the DOH Division of Environmental Health Office of Drinking Water (ODW) website. Washington State Office of Financial Management (OFM) census data was also used to verify the value derived from the DOH data. Two OFM census tracts are completely contained within WRIA 47, while two others cover only a small portion of WRIA 47. The tracts completely within WRIA 47 are 9603 and 9604. These cover the majority of the Wapato basin, which contains the majority of the populated area. Census tract 9601 covers the majority of the Lucerne basin as well as Entiat WRIA 46. Census tract 9710 follows the Okanogan County line, covering the upland area of the Antoine Creek sub-watershed. The OFM data shows that the 2008 population for the two tracts contained within WRIA 47 was 10,623. Approximately 3,000 more people reside outside of these tracts based on the data from the other census tracts.

Total water use was calculated based on the total number of connections provided by the agencies listed above, the Group A Communities listed in the DOH ODW water system database (minus inactive and multiple sources serving the same system), plus domestic use supplied by exempt wells.

The majority of residences in WRIA 47 are served by Group A Community water systems. The City of Chelan serves 7,407 while the Lake Chelan Reclamation District (LCRD) serves 3,220. The next largest purveyor, Chelan Falls Water District, serves 380 residents; this purveyor uses a groundwater source that is in direct hydraulic continuity with the Columbia River.

The following sources were used to calculate the volume and quantity of residential water consumption.

- Group A communities with metered values, including the City of Chelan, the LCRD and Chelan Ridge.

- Group A Community use based on per capita consumption rates, including the following purveyors.

Group A Communities	Population
Chelan Falls Water District	380
Apple Acres Village	212
Chelan Co PUD - Chelan Ridge	90
Sunnybank Water System	89
Lakeview Utilities	79
Holden Village	64
Chelan Park Ranches Water Assn	52
Little Butte Water System	48
Snow Creek Water System	41
Azwell Orchards	28

Two consumption rates were used: 1) 215 gallons per day based on the per capita consumption rate in the City of Chelan from 2004 to 2007; 2) 350 gallons per day per residence following the DOH ODW *Water System Design Manual*. (The reader should make note of the fact when following the calculations that the first number, 215 gallons is per person, while the 350 gallons is per residence.)

Based on the data available, the population served was either multiplied by the per capita rate or converted to number of residences (assuming a occupancy rate of 2.624 people per residence based on OFM census data) The calculations based on residences or households were multiplied by the 350 gallons per residence value promulgated by the DOH *Surface Water Design Manual*. These consumption rates were then multiplied by 365 days to estimate average annual use.

Local data indicating the amount of water consumed for indoor uses were not available. However, the *Water System Design Manual* indicates that Washington State average domestic water use rarely drops below 200 gallons per day (gpd) regardless of rainfall. Therefore, an indoor consumptive rate of 200 gpd was used for this estimate. Average outdoor use is estimated to be the difference between the total consumption rate and the indoor consumptive rate, or 150 gpd.

Results

Values were calculated to show whether a source of domestic water was groundwater or surface water. Approximately 11 percent of households receive water from WRIA 47 groundwater sources, with 89 percent from surface water (**Table 4-1**). Next, estimates were shown for the number of connections and populations served by Group A and B water systems and exempt wells in **Table 4-2**. Group A water systems supply 89 percent, exempt wells supply 7 percent and Group B water systems supply 4 percent of water used in WRIA 47. The distribution of potable water systems is shown on **Figure 4-1**.

Table 4-1 – Domestic Water Sources in WRIA 47[1]

	Population[2]	Percent of Total Residences
Groundwater[3]	1,501	11%
Surface Water	11,710	89%
Total	**13,211**	**100%**

[1]The Antoine Creek sub-watershed is not included in analysis.
[2]Based on DOH, ODW Community Group A populations served and an assessment of exempt wells.
[3]Not including Chelan Falls Water District

Table 4-2 – Domestic Water Use in WRIA 47

	Population Served	Total Use Metered Values (AFY)	Total Use Consumption (AFY)		Indoor (AFY)	Outdoor (AFY)
Group A			*215 gal/person*	*350 gal/residence*		
City of Chelan	7,407	1,400	-	-	626	774
Lake Chelan Reclamation District	3,220	805	-	-	272	533
Chelan Ridge	90	27	-	-	8	20
Remaining Community Systems	993		237	147	84	153
Group B and Group A Non-community systems	542		129	53	30	99
Exempt Wells	959		229	142	81	148
Total population served	**13,211**					
Total based on metered values		2,232				
Total based on DOH population				341		
Total based on per capita consumption			594			
Total volume from residential consumption			**2,826**	**2,573**	**1,101**	**1,725**

Approximately 90 percent of wastewater is treated at the City of Chelan Wastewater Treatment Plant (CCWTP); in addition, approximately 60 percent of the LCRD domestic water service area is also piped to the CCWTP. The outflow for this plant is the Columbia River, thus almost all Group A indoor domestic water use, and hence the vast majority of indoor domestic water consumption, is exported out of the watershed. In contrast, the water applied as irrigation re-enters the watershed as groundwater infiltration if it passes the root zone of the plants and is not lost through evapotranspiration.

Potential Sources of Error

The number of residences depending on exempt wells for supply (959 residences) was estimated by searching and screening the number of exempt wells listed in Ecology's well logs. This number represents those wells that supply domestic-use water and were within a specific diameter (6 to 8 inches) known to provide domestic water supply. Wells were excluded if they were classified as "Resource Protection" or "Abandoned". RH2 assumed wells with a diameter smaller than 6 inches were associated with a "Resource Protection" well and those well with a diameter larger than 8 inches would be associated with a water right and thus included in either the Office of Drinking Water or the Water Rights Application Tracking System GIS database, called the Geographic Water Information System (GWIS).

The 959 well borings reported in Ecology's database and not attached to a certified or permitted right is significantly lower than the number of residences potentially relying upon exempt well water sources. Several possible reasons for this difference include the following.

- Ecology did not require exempt well reporting before 1971 and did not enforce well reporting until 1992. Ecology estimates that 30 percent of wells drilled before 1992 were not reported.
- Up to six residences can be served by a single exempt well.
- Some households receive domestic water from springs.
- A few residences may haul water for supply.
- The estimated number of households may not reflect actual conditions.

Another potential source of error in the domestic use calculation includes those potential supply wells that derive a portion of groundwater withdrawal from recharge through aquifers in hydraulic continuity with the Columbia River. This potential undocumented importation of water into the watershed is likely restricted to wells completed within flood deposits or alluvial aquifers within ½-mile of the river.

Also, domestic indoor use associated with household consumption may not reflect actual use as household size and/or seasonal occupation may vary. This may be especially prevalent within Group B and Group A non-community systems. Many of these households may be either occupied seasonally or be a system associated with non-residential use (e.g. a mobile home park).

4.1 INDUSTRIAL AND COMMERCIAL WATER USE

Major industrial and commercial water users were identified by examining water rights. Industrial and commercial water users and water use are summarized in **Table 4-3**. The City of Chelan meters their users, at the time of this report metered consumption for the years 2004 through 2007 was an average of 504 AFY. This value encompasses all consumption not included in the residential tally: institutional, commercial and municipal uses. Given the difficulty in estimating the amount of water returned via infiltration and the relatively small component of the water balance, all commercial and municipal water use was assumed to be a loss to the WRIA 47 water balance.

Table 4-3 – Commercial and Industrial Use Water Rights Volumes

	Instantaneous Quantity (gpm)	Acre-feet per Year (AFY)
Chelan River Irrigation District (Wapato Main Stem)	799.2	273
Jack Sibert (Howard Flats)	40	65
S. A. Lepley (Wapato Main Stem)	103.3	54
Chelan Concrete Co. Inc. (Wapato Main Stem)	50	20
Lakeshore Orchards (Wapato Main Stem)	40.4	14.4

4.2 IRRIGATION WATER USE

Method

Several irrigation districts were contacted to inquire about crop types and distributions, but none could provide an accurate account, presumably due lack of centralized information and annual changes in crop cover. The most definitive basin-wide assessment of crop distribution is a 1988 report which states 11,500 acres covered by orchards and 7,500 acres in non-orchard agriculture, the majority being dry land wheat. In addition, a GIS analysis of crop cover was preformed, using a land cover file published by the USDA/NRCS, National Cartography and Geospatial Center titled, USDA-NAS Cropland Data Layer. The data shows land cover for the United States and was created from imagery processed from 1997 to 2006. Each cell in the raster data file represents a 30-meter by 30-meter square. The value calculated using this analysis was found to be grossly low compared to the approximate values of the 1988 survey and more recent values and thus discarded.

Results

GIS analysis shows the approximate *location* of the land cover committed to agriculture, (but, again, due to the limits of data accuracy actual acreage was not used). The land classes described in the USDA/NASS data are alfalfa, apples, winter wheat and other crops. The great majority of agriculture was shown to occur in the LCRD boundary, falling within the Manson Lakes and Wapato Main Stem sub-basins. The LCRD was contacted and found to have 6,472.6 acres under irrigation. They recorded an average water consumption of 16,009 AFY since 1987. This translates to 29.68 inches over the 6,472.6 irrigable acres. Further, a LCRD staff contacted via email noted that crop cover has changed dramatically over the last 5 to 8 years: apples and cherries are expanding. In addition, wine grapes are becoming more prevalent in the district. The LCRD staff also noted that more recently, due to the current economic recession, many farmers are laying their land fallow and some irrigation water rights are being used for domestic supply. Water use for the LCRD and other smaller irrigation districts within this area are summarized in **Table 4-4**.

Table 4-4 – Irrigation District Consumption

	Instantaneous Quantity (cfs)	Total Use (AFY)
Lake Chelan Reclamation District	116.7	16,009
Chelan Falls Irrigation District	5.0	1,700
Chelan River Irrigation District	6.7	2,000
Isenhart Irrigation District	4.0	1,250

Of the amount of water that is applied to a crop, approximately 5 percent to 15 percent is lost to evaporation (spray evaporative loss, canopy loss, or wind drift), while up to an additional 15 to 30 percent of agricultural water can be lost due to application inefficiencies, either as surface runoff or deep percolation. This surface runoff and water which percolates beyond the root zone of the plants stays within the watershed due to the local geology (discussed above) though potentially lost to that sub-basin. The volume of irrigation water taken up by plants and exported out of the system is approximately 55 percent, up to 100 percent in highly efficient operations.

Potential Sources of Error

Several assumptions that could affect the values presented above. The reader should consider that the data regarding irrigation methods for each irrigation district was an average but this discounts increasing irrigation efficiency, selection of crops by farmers, changing weather patterns, farmers' reaction to market demand or water reallocation.

Section 5 – Water Balance

Water balance accounts for inputs, outputs and returns to the hydrologic system. By definition, once all components have been quantified, the water balance should be zero. However, in practice, it is impossible to measure and account for all components of the water balance, as even in well-instrumented basins with numerous, long-term data sources. Therefore, water balance estimates are intended to identify the relative importance of each water balance component. Although a water balance may account for average water inputs, outputs and returns during a particular year, it does not consider the cumulative effects of previous years. The climatic and water use conditions of the past several years will affect the outcome of a water balance for any given year.

Typical water balance approaches examine input and output components to the hydrologic system by primarily analyzing precipitation (input) and stream flow data (output). Precipitation and stream flow are the significant components of a water balance, and long-term monitoring data for these components are available for WRIA 47.

Figure 5-1 schematically illustrates the components and relationships of a water balance.

5.0 PREVIOUS ESTIMATES

The water balance of Lake Chelan has been estimated several times since 1975, and results are generally comparable. The estimates relied upon flow data for major and minor tributaries, estimates or measurements of water use, and assumptions of water loss from evapotranspiration and groundwater recharge and water gain from irrigation return flow, imported water and groundwater discharge.

The initial water budget for Lake Chelan used stream flow data and water use estimates (Ecology 1975). **Table 5-1** summarizes the initial water balance.

Table 5-1 – WRIA 47 Water Balance (1975) excluding Columbia River Sub-basins

Source	Average Flow (AFY)	Use	Quantity (AF/year)	Percent Consumed
Precipitation	+ 2,706,000	Hydroelectricity	1,415,500	0
Evapotranspiration	- 1,490,000	Irrigation	16,600	60 to 90
Runoff	- 1,216,000	Municipal	1,500	10 to 30
		Industrial	650	Unknown
		Domestic	350	10 to 30
		Stock	100	100

A 1981 study of the Lake Chelan water budget used surface water flow data and estimates of evaporation and irrigation withdrawal to calculate the potential quantity of groundwater discharge to Lake Chelan. **Table 5-2** summarizes the budget below.

Table 5-2 – Water Budget of Lake Chelan for 1976-1980 (in AF per year)

Net Inflow to Lake	Surface Water	Groundwater	Precipitation	Evaporation	Irrigation Withdrawal	Irrigation Return
1,589,470	910,676	199,737	517,247	71,929	(75,325)	(34,795)
100%	70%	33%	4.5%	-4.7%	-2.2%	1.3%

A detailed yearly water budget for Lake Chelan was prepared for the Lake Chelan Water Quality Assessment Project (Ecology, 1989; **Table 5-3**). The water budget was based on stream flow and precipitation data that was collected between December 1986 and November 1987, and then adjusted to reflect long-term conditions. The study included estimates of evaporation and rates of runoff. Note that this study concluded that groundwater input is a "relatively minor" component of inflow to Lake Chelan, in contrast to the conclusions of the 1981 estimate. The study also concluded that water withdrawn from the lake for irrigation was estimated at 1 to 2 percent of the total water balance, and of this, 10 to 40 percent is estimated to return as drain flow and groundwater recharge.

Table 5-3 – Low Flow Period Water Budget of Lake Chelan for 1987 (in AF/year)

Net Outflow from Lake	Surface Water	Precipitation	Evaporation	Irrigation Withdrawal
(1,490,000)	1,570,000	69,427	-66,534	-15,900

In 1995, Ecology (**Table 5-4**) prepared an initial watershed assessment using the data from the 1989 estimate and revised irrigation and domestic use according to irrigation and census records.

Table 5-4 – Revised Water Balance Estimate for Lake Chelan (Ecology, 1995)

	Annual Quantity		
Component	**Average Volume (acre-feet)**	**Average Flow**	**Percent of Total**
Inflows			
Stehekin River	1,023,321	1,415	65.2
Railroad Creek	147,532	204	9.4
Upper Basin Tributaries	316,759	438	20.2
Lower Basin Tributaries	9,329	12.9	0.6
Stormwater Runoff	3,254	4.5	0.2
Agricultural Drains	651	0.9	0.0
Direct Precipitation	69,427	96	4.4
Total Inflow	**1,570,056**	**2,171**	**100.0**
Outflow			
Chelan River	1,487,612	2,057	94.7
Irrigation Withdrawal	15,910 to 34,560	22 to 47.7	1.0 to 2.2
Evaporation	66,534	92	4.2
Total Outflow	**1,570,056**	**2,171**	**100.0**

Water Balance of WRIA 47 Sub-basins

The water balance was calculated for each WRIA 47 sub-basin using precipitation and evapotranspiration rates based on climate station data. The estimates were developed for average, dry/warm and wet/cool years (**Tables 5-5, 5-6** and **5-7**). The water balance for dry/warm and wet/cool years examines the potential range of water availability during extreme climate conditions in the watershed. A dry/warm year represents climatic conditions at the lowest annual precipitation and highest annual average temperatures. A wet/cool year represents highest annual average precipitation and lowest annual average temperatures during the period of record. Estimated withdrawals and subsequent return flow for beneficial uses within the sub-basin, and estimated groundwater recharge were included to illustrate the difference in natural and artificial exchanges of water compared to the primary components of precipitation and evapotranspiration.

Potential runoff was determined from the difference between precipitation and evapotranspiration (Precipitation – actual evapotranspiration) and compared to stream gauge data. Potential runoff and stream flow were within 10 percent, indicating that groundwater recharge is likely within 1 to 10 percent of total precipitation, which would be expected for areas underlain predominantly by bedrock, as in the upper elevation sub-basins and the arid climate of the lower elevation sub-basins. The water balance estimates indicate that regardless of the type of year (normal, wet, dry) the relative proportions of water flow into WRIA 47 are consistent.

Table 5-5 – Summary of Precipitation and Evapotranspiration – Average Year (1916 to 2008 period of record)

Sub-basin	Total Area (ac)	Precip. (AF)	Percent of Lake Chelan Sub-basins	Precip. (in)	AET[1] (in)	Precip - AET (in)	Precip - AET (AF)	Percent of Lake Chelan Sub-basins	Percent of WRIA 47	River Flow at Gauge (AF)	Groundwater Recharge Rate[2]	Groundwater Recharge from Precip (AF)
Stehekin	218,576	1,246,100	53	68.4	12.8	55.6	1,012,951	60	58.1	1,085,276	1	12,461
Lucerne Main Stem	209,048	683,090	29	39.2	12.8	26.4	460,106	27	26.4		1	6,831
Railroad Creek	41,553	173,966	7	50.2	12.8	37.4	129,642	8	7.4	153,488	1	1,740
Columbia River Tributaries.	35,726	51,093	-	17.2	10.2	7.0	20,726	-	1.2		10	5,109
Lake Chelan	33,344	69,427	3	25.0	28.6	-3.6	(10,043)	-1	-0.6		0	-
Wapato Main Stem	30,548	40,390	2	15.9	10.2	5.7	14,424	1	0.8		10	4,039
25-mile Creek	27,078	77,227	3	34.2	12.1	22.1	49,923	3	2.9		1	772
Manson Lakes	24,974	45,075	2	21.7	10.2	11.5	23,847	1	1.4		10	4,507
Antoine	21,059	41,160	-	23.5	12.0	11.5	20,102	-	1.2		10	4,116
Howard Flats	11,807	16,982	-	17.3	12.0	5.3	5,175	-	0.3		10	1,698
First Creek	11,634	28,547	1	29.4	12.0	17.4	16,914	1	1.0		1	197
Total	**653,713**	**2,444,509**		**44.9**			**1,743,767**		**100**			
Lake Chelan only	596,756	2,363,822	97				1,697,764			1,886,744		30,350
Columbia River only	56,957	80,688	3				46,003					

[1] AET values based on average AET measured at separate climate stations.
[2] Estimated based on permeability of predominant geologic units.

Table 5-6 – Summary of Precipitation and Evapotranspiration – Warm/Dry Year (1944)

Sub-basin	Total Area (ac)	Precip. (AF)	Percent of Lake Chelan Sub-basins	Precip. (in)	AET[1] (in)	Precip - AET (in)	Precip - AET (AF)	Percent of Lake Chelan Sub-basins	Percent of WRIA 47	River Flow at Gauge (AF)	Groundwater Recharge Rate[2]	Groundwater Recharge from Precip (AF)
Stehekin	218,576	772,067	51	42.4	11.9	30.5	555,312	62	58.3	647,980	1	7,721
Lucerne Main Stem	209,048	453,125	30	26.0	14.4	11.6	202,268	23	21.2		1	4,531
Railroad Creek	41,553	119,129	8	34.4	14.4	20.0	69,264	8	7.3	92,672	1	1,191
Columbia River Tributaries	35,726	38,433	-	12.9	4.0	8.9	26,524	-	2.8		10	3,843
Lake Chelan	33,344	48,599	3	25.0	28.6	-3.6	(10,003)	-1	-1.1		0	-
Wapato Main Stem	30,548	31,698	2	12.5	4.0	8.5	21,515	2	2.3		10	3,170
25-Mile Creek	27,078	54,843	4	24.3	14.4	9.9	22,350	2	2.3		1	548
Manson Lakes	24,974	29,523	2	14.2	4.0	10.2	21,198	2	2.2		10	2,952
Antoine	21,059	26,883	-	15.3	4.0	11.3	19,864	-	2.1		10	2,688
Howard Flats	11,807	12,364	-	12.6	4.0	8.6	8,428	-	0.9		10	1,236
First Creek	11,634	19,678	1	20.3	4.0	16.3	15,800	2	1.7		1	297
Total	**653,713**	**1,586,664**		**29.1**			**952,521**		**100.0**			
Lake Chelan only	596,756	1,528,662	96				897,705			844,980		20,311
Columbia River only	56,957	58,002	4				54,816					

[1] AET values based on average AET measured at separate climate stations.
[2] Estimated based on permeability of predominant geologic units.

Table 5-7 – Summary of Precipitation and Evapotranspiration – Wet/Cool Year (2006)

Sub-basin	Total Area (ac)	Precip. (AF)	Percent of Lake Chelan Sub-basins	Precip. (in)	AET[1] (in)	Precip - AET (in)	Precip - AET (AF)	Percent of Lake Chelan Sub-basins	Percent of WRIA 47	River Flow at Gauge (AF)	Ground-water Recharge Rate[2]	Groundwater Recharge from Precip (AF)
Stehekin	218,576	1,360,143	52	74.7	12.8	61.9	1,126,995	59	58.0	1,413,972	1	13,601
Lucerne Main Stem	209,048	778,375	30	44.7	14.4	30.3	527,517	28	27.1		1	7,784
Railroad Creek	41,553	211,377	8	61.0	14.4	46.6	161,513	8	8.3	217,200[3]	1	2,114
Columbia River Tributaries	35,726	56,695	-	19.0	13.6	5.4	16,206	-	0.8		10	5,670
Lake Chelan	33,344	76,370	3	25.0	13.6	11.4	31,677	2	1.6		0	-
Wapato Main Stem	30,548	46,808	2	18.4	28.6	-10.2	(25,997)	-1	-1.3		10	4,681
25-Mile Creek	27,078	85,194	3	37.8	13.6	24.2	54,506	3	2.8		1	852
Manson Lakes	24,974	42,071	2	20.2	13.6	6.6	13,767	1	0.7		10	4,207
Antoine	21,059	39,742	-	22.6	13.6	9.0	15,876	-	0.8		10	3,974
Howard Flats	11,807	19,010	-	19.3	13.6	5.7	5,629	-	0.3		10	1,901
First Creek	11,634	29,708	1	30.6	14.4	16.2	15,747	1	0.8		1	-
Total	**653,713**	**2,715,786**		**49.9**			**1,943,436**		**100.0**			
Lake Chelan only	596,756	2,630,046	97				1,905,725			1,487,820		33,536
Columbia River only	56,957	85,740	3				37,711					

[1] AET values based on average AET measured at separate climate stations.
[2] Estimated based on permeability of predominant geologic units.
[3] 1957 data

Natural flow and beneficial uses (water rights) are summarized in **Table 5-8**. This summary shows the significant components in the water balance for WRIA 47; however, it excludes the non-consumptive diversion for hydropower. The source of most diversion for irrigation and municipal/domestic supply derives from Lake Chelan. Most of the water is applied to the Manson Lakes and Wapato Main Stem Sub-basins. Irrigation return recharges groundwater within these basins and is either withdrawn for use or discharges into Lake Chelan. Treated municipal wastewater is routed out of the watershed to discharge into the Columbia River, and smaller domestic wastewater is discharged to ground and ultimately returns to Lake Chelan.

Table 5-8 – Comparison of Natural Flows to Water Rights

Sub-basin	Total Area (ac)	Precip. (AF)	Precip - AET (AF)	River Flow at Gauge (AF)	Surface Water Rights (AF)	Groundwater Rights (AF)
Stehekin	218,576	1,246,100	1,012,951	1,013,600	-	-
Lucerne Main Stem	209,048	683,090	460,106		445	-
Railroad Creek	41,553	173,966	129,642	144,800	-	-
Columbia R Tributaries	35,726	51,093	20,726		CR[1]	CR
Lake Chelan	33,344	69,427	(10,043)		-	-
Wapato Main Stem	30,548	40,390	14,424		30,907	434
25-mile Creek	27,078	77,227	49,923		398	-
Manson Lakes	24,974	45,075	23,847		14,217	589
Antoine	21,059	41,160	20,102		1,846	CR
Howard Flats	11,807	16,982	5,175		CR	CR
First Creek	11,634	28,547	16,914		1,631	-
Total	**655,347**	**2,473,057**	**1,743,767**		**49,444**	**1,023**
Lake Chelan only	596,755	2,363,822	1,697,764	1,487,820	47,598	1,023
Columbia River only	56,958	80,687	46,003		CR	-

[1]CR – derived primarily from surface water outside Lake Chelan sub-basins or groundwater in continuity with Columbia River.

The irrigation and municipal diversions place a small demand on the runoff component (precipitation minus evapotranspiration) of the water balance for all sub-basins. The source of water for beneficial use derives from the collective storage in Lake Chelan. Approximately 85 percent of the lake water derives from runoff from the Stehekin and Railroad Creek Sub-basins, which is able to support the withdrawals in the lower sub-basins where runoff rates are only a few percent of the total water balance. These lower sub-basins benefit from irrigation return flow that substantially augments the natural groundwater recharge from infiltration of precipitation, which increases groundwater availability and base flow in these sub-basins.

Section 6 – Summary and Recommendations

This section summarizes key findings of the water quantity assessment, identifies needed data that would improve understanding of the quantity and availability of water, and recommends actions for data collection and analysis that would improve water management in the watershed.

6.0 KEY FINDINGS

6.0.1 Water Balance

During normal water years, WRIA 47 receives more than 2 million acre-feet (AF) of precipitation, loses approximately one-third of that to evapotranspiration and discharges more than 1 million AF of runoff through the Chelan River. Approximately 90 percent of precipitation and evapotranspiration occurs on federal lands, and essentially all of the surface water discharged from WRIA 47 is regulated through a Federal Energy Regulatory Commission (FERC) license. The greatest non-hydropower beneficial uses of water in WRIA 47, irrigation and domestic use, occur in the Wapato Mainstem and Manson Sub-basins, and water stored in the Lake Chelan Basin supports these demands. Annual irrigation water and domestic water rights for these sub-basins represent less than 5 percent of the more than 1 million AF of runoff from the watershed. These percentages within the WRIA 47 water balance create the appearance of abundant water availability for new diversion and uses. However, water right law prevents unrestricted development of new sources that could impair senior rights. Future water demands that would be most readily developed from Lake Chelan storage may occur, but only within the conditions of the FERC license and associated water right.

6.0.2 Land Use

Much of the land use, and therefore water use, in the watershed is federally-managed. The United States Forest Service (USFS) and National Park Service (NPS) land use policies affect the largest area of the watershed and potentially have the greatest man-made influence on surface water flow in the watershed. Therefore, watershed planning must align with federal land use planning. Irrigable land area in the watershed is constrained by land ownership, topography, soil and geologic conditions, and the distance from irrigable land to the lake shore or an irrigation system conveyance. Approximately 50 percent of irrigable land in the Manson Lakes Sub-basin is irrigated or could be irrigated if water was available. As irrigated land converts to less water intensive and/or high value crops or domestic use, water use and return flows within sub-basins will respond to these changes.

6.0.3 Water Rights and Water Use

The largest water use, hydropower, is managed by FERC license to Public Utility District No. 1 of Chelan County (Chelan PUD). The FERC license governs the lake level and the timing and rate of dam release, which affects access to water. Therefore, watershed planning that involves surface water must align with FERC license requirements.

As irrigation water use changes with crop and land conversion, irrigation return flow will affect groundwater recharge and local base flow. Current water law and policy will constrain the conversion of water rights from seasonal irrigation to year-round domestic use.

Groundwater withdrawals are a minor component of the watershed water budget, and are primarily for domestic use. The demand for new groundwater supplies will be constrained by the limited availability of water in the surficial aquifer in areas not already appropriated for groundwater withdrawal.

6.1 ADDITIONAL DATA NEEDED TO IMPROVE UNDERSTANDING OF THE QUANTITY AND AVAILABILITY OF WATER

Surface water flow data are sufficient to manage Lake Chelan levels and flow. However, irrigation water use has proven difficult to quantify due to the lack of reliable long-term metering data. Changes in crop patterns and water demands are not well documented, but are needed to support forecasting future demands for irrigation supply.

Available smaller tributary flow data are sporadic and not currently useful for analyzing trends or estimating availability. However, the available runoff data indicates that these tributaries contribute a relatively insignificant quantity to the water budget. Tributary monitoring in smaller sub-basins would support evaluation of surface water availability for beneficial use within the sub-basin.

Groundwater use in WRIA 47 from sources not in hydraulic continuity with the Columbia River is primarily from wells that support limited withdrawals for domestic use. Groundwater elevation data are sporadic and currently not useful to evaluate trends of groundwater availability, demand or influence on stream flow. Compilation and mapping of groundwater data would identify areas that could rely on local groundwater sources or areas that would require importing surface water to meet future growth. Since much of the groundwater recharge into the surficial aquifer derives from irrigation and septic return flow, groundwater level monitoring could support the evaluation of the effects of land and water use changes on surficial aquifer recharge and base flow.

Groundwater use from exempt wells within the watershed is not well documented. The Department of Ecology (Ecology) records for well installation are incomplete for dates before 1992 when drillers were not required to file a notice of intent. The quantities of groundwater withdrawn for consumptive use and returned as recharge are variable depending on land and water use, occupancy and soil types. The future availability of water may be constrained if the net effect of withdrawals exceeds recharge. A more detailed survey of groundwater use from exempt wells would support forecasting of future groundwater availability and potential regulation of groundwater withdrawal from exempt wells.

6.2 ACTIONS, DATA COLLECTION AND ANALYSES TO IMPROVE WATER MANAGEMENT

6.2.1 Improve Data Collection for Water Use

Large retail water purveyors currently meter water use and report these data to the Washington State Department of Health. Irrigation districts meter water use, but these data are not readily available for watershed planning purposes. Other irrigation water use records for private water rights are dispersed among dozens of ownerships and will be very difficult to collect and compile. If watershed planning goals include tracking irrigation supply, demand and return flows, irrigation districts and private water right holders could participate in a water use network to provide a demand and forecasting tool for future growth and management of drought periods.

Changes in crop cover and irrigation practices may have a large impact on the sub-basin. Documenting the annual crop type in association with water use would also support watershed planning to evaluate the potential or actual effects of water use on surface flow in streams and groundwater levels.

6.2.2 Climate Change

The majority of water supply in WRIA 47 originates as precipitation in the upper sub-basins. Climate change may impact snow pack via a change in overall quantity of snow fall, change in snow level (exponential reduction in surface area due to typical cone shape of mountains), timing of winter storms and ensuing spring melt, and/or frequency of storms.

Current data collection includes an Ecology stream gauge at the Stehekin River mouth, one WRCC COOP Station on the Stehekin River (3 NW), and two SNOTEL sites (Park Creek Ridge and Rainy Pass). These data sources will continue to support the evaluation of long-term trends of water availability in the largest tributaries. This information becomes more important during dry years as the contribution from the Stehekin Basin to the entire watershed increases.

Watershed planning efforts should consider how to interpret available stream gauge data to reflect the potential availability of water in smaller sub-basins or install and monitor local stream gauges should water demands increase in smaller sub-basins.

6.3 FUTURE WATER NEEDS/METHODS TO RESERVE WATER FOR HIGH PRIORITY PURPOSES AND PLACES OF USE

6.3.1 Population Change

Annual population growth trends in the Wapato and Manson Lakes Sub-basins (1.7 percent) and in less populous smaller sub-basins (1.3 percent) suggest a 30 percent growth from 2008 to 2025. Water to meet this population growth will come from municipal supplies derived from Lake Chelan storage and private domestic wells. Municipal purveyors (City of Chelan and Lake Chelan Reclamation District, for example) will perfect more of their inchoate rights to meet the future demand, and private well owners will rely on permit exempt rights. The largest municipal purveyors have inchoate rights or current water right applications to meet demand into 2050. Beyond this period, new sources of supply would likely be derived from Lake Chelan storage.

New large scale planned communities outside municipal purveyor service areas will convert irrigated lands to domestic use. These lands may come with irrigation rights that may be transferred to domestic use, which may not require additional appropriation of water for the new development. However, if these developments occur within an irrigation district service area, the water will remain with the district for irrigation purposes. Other non-irrigation purposes of the development must obtain a new source of water, likely from Lake Chelan storage. The irrigation rights for the irrigated lands within the development that are converted to impervious or fallow features will be relinquished to the district for use on other lands within the district's boundary. Developments outside existing irrigated lands will likely need to obtain all their water supplies from Lake Chelan storage.

6.3.2 Irrigation Demand

Irrigation water supply is limited by the economics of pumping and piping water to un-irrigated lands. The demand for high-value crops such as cherries and grapes will likely drive new demand for irrigation water. Water for portions of this future demand will be met from the existing water rights of the irrigation districts. As some irrigation rights are relinquished back to the irrigation district, other lands will be waiting to accept the available rights. The net result is no additional gain or loss in supply. Areas outside of the irrigation district could sustain commercial agriculture, but it is not currently economical to develop. Where it is economical to develop additional agricultural land, an estimated application rate of 30 inches per acre for Lake Chelan Reclamation District irrigated lands may be used for forecasting demand. An additional 2,000 acres of irrigable lands (approximately one-third the current amount irrigated in the Lake Chelan Reclamation District service area) is estimated outside of the irrigation district boundary and would require 5,000 AF of irrigation supply. The source would derive from Lake Chelan storage or the Columbia River if in the Columbia River sub-basins.

6.3.3 Commercial/Industrial Demand

The combined annual quantity of commercial and industrial water rights is 360 AF per year in Lake Chelan Sub-basins and 65 AF per year in the Howard Flats Sub-basin (**Table 4.3**). Future supply for commercial and industrial use will develop with new industrial and commercial growth. No new facilities in the watershed are forecasted, and growth could be expected at the same pace as residential growth. Watershed planning should identify the type and timing of potential new industrial and commercial operations and determine their potential water supply requirements.

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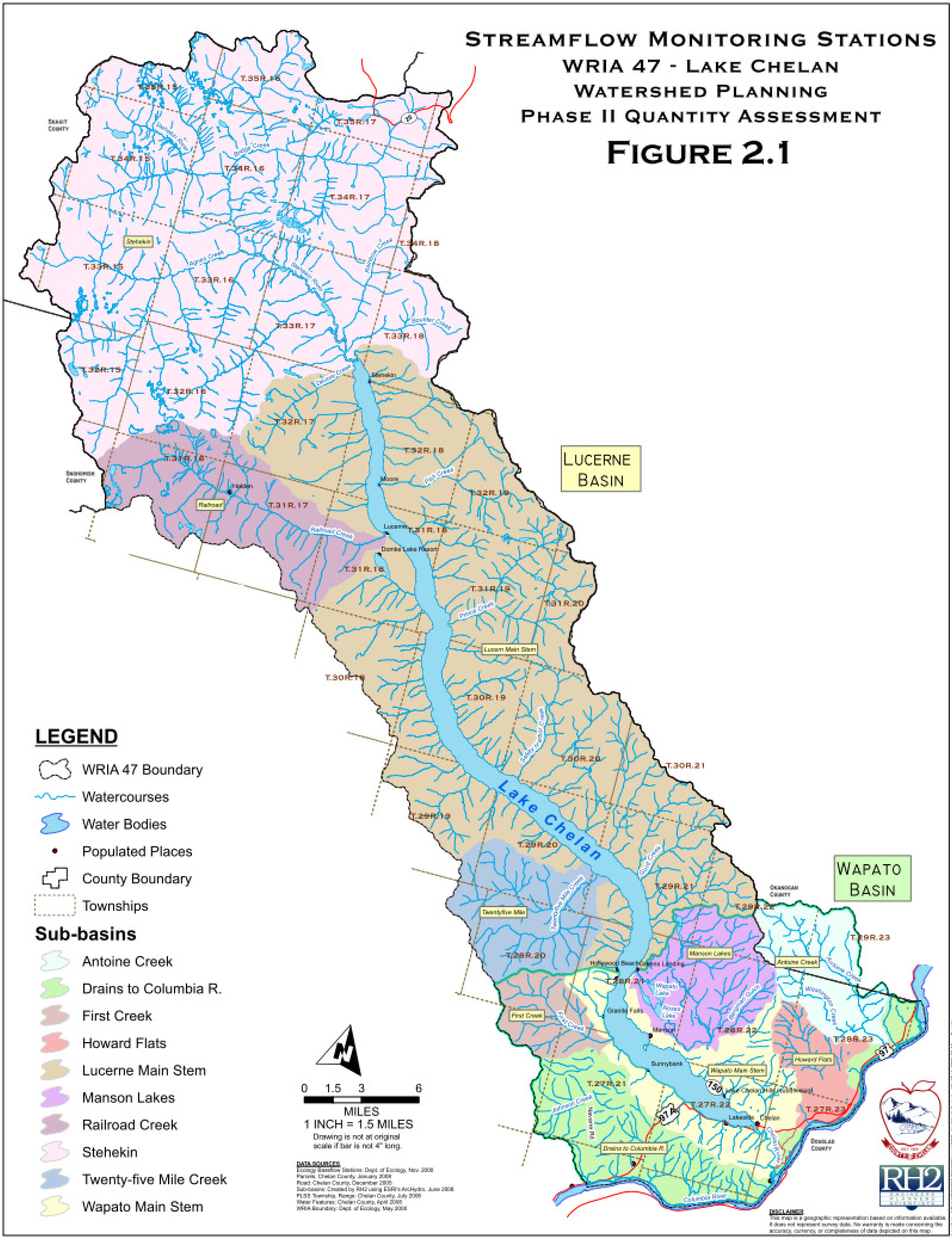
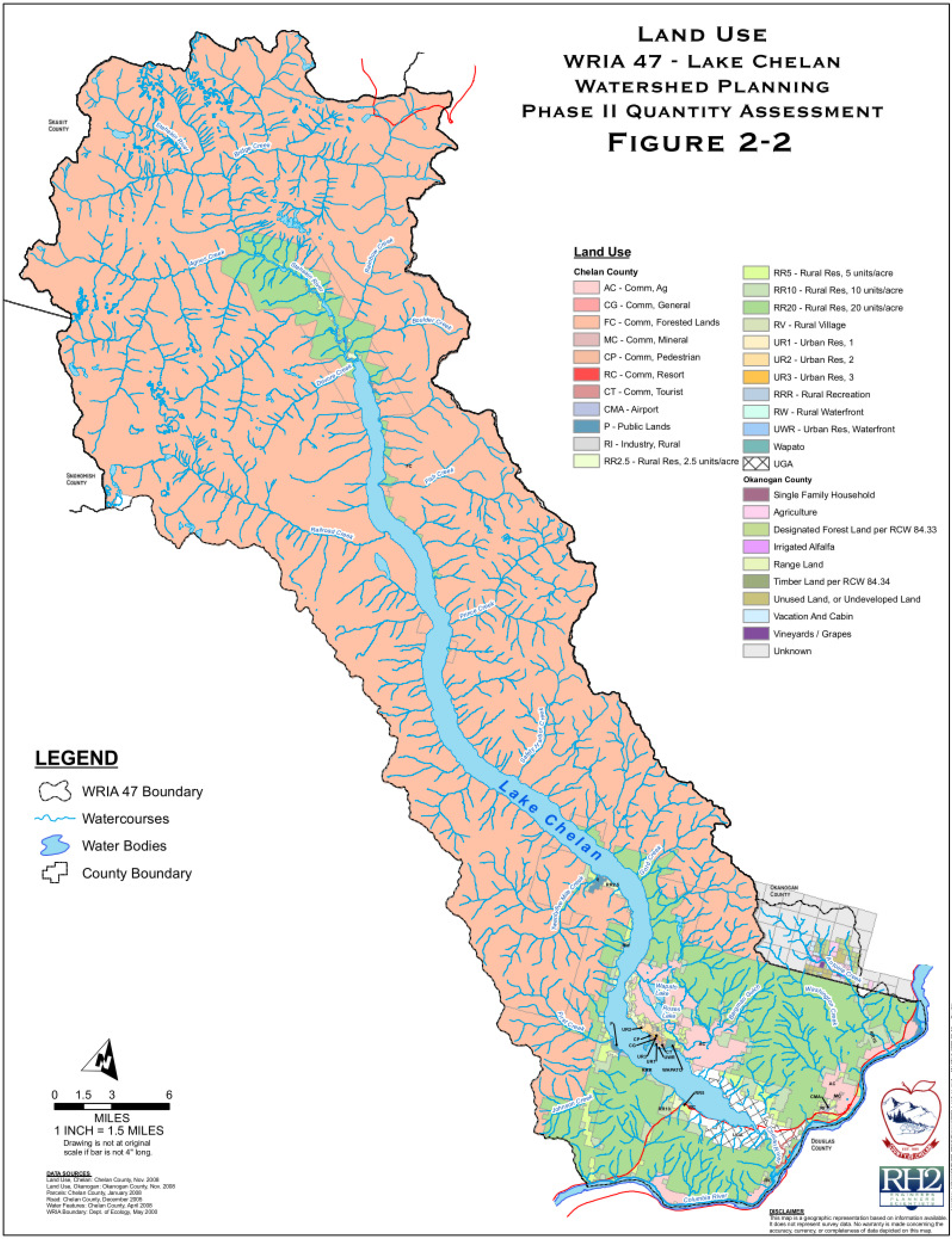
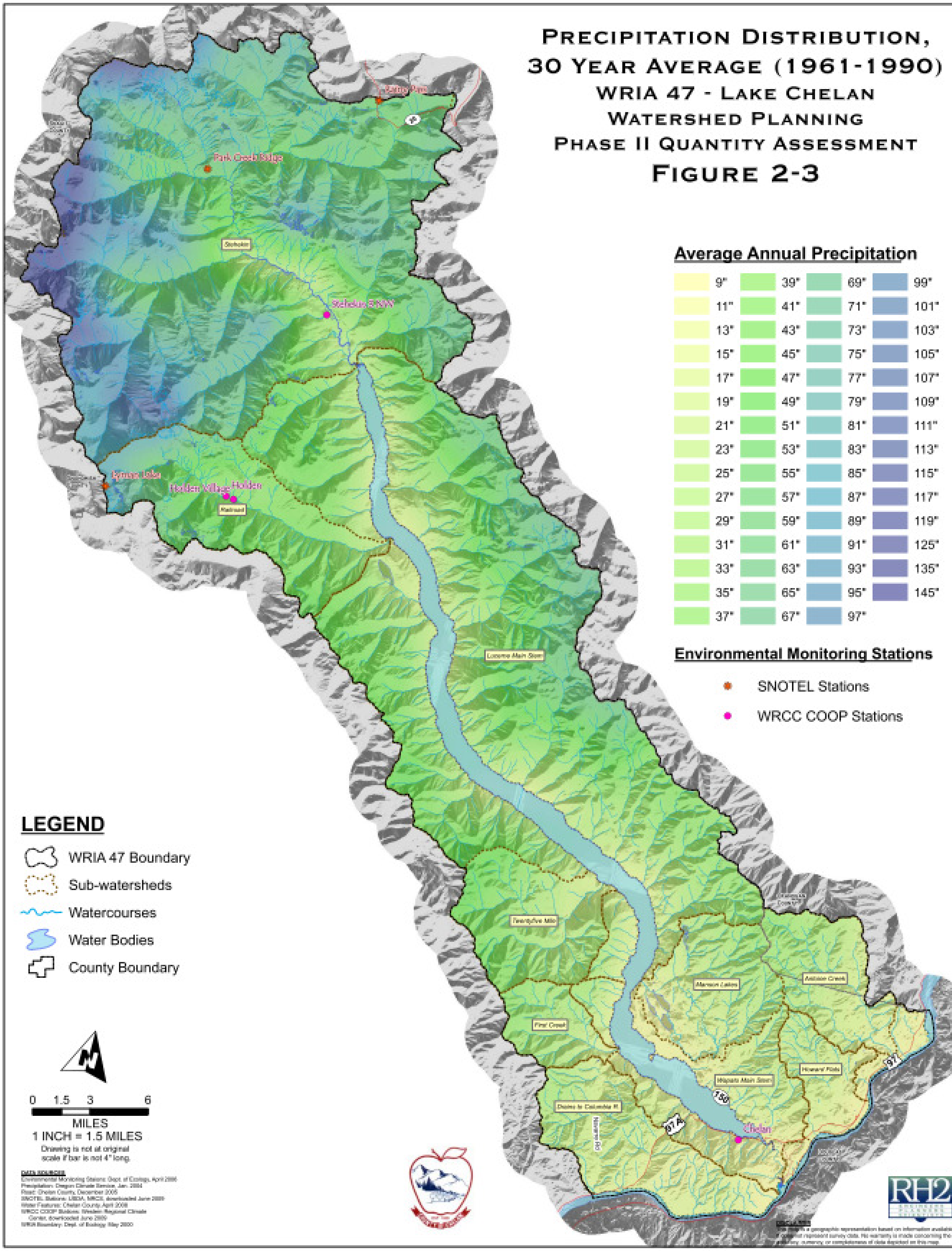


STREAMFLOW MONITORING STATIONS
WRIA 47 - LAKE CHELAN
WATERSHED PLANNING
PHASE II QUANTITY ASSESSMENT
FIGURE 2.1
LUCERNE BASIN
WAPATO BASIN
Lake Chelan
Stehekin
Railroad
Lucern Main Stem
Twentyfive Mile
First Creek
Manson Lakes
Antoine Creek
Howard Flats
Wapato Main Stem
Drains to Columbia R.
Stehekin
Holden
Moore
Lucerne
Domke Lake Resort
Hollywood Beach
Greens Landing
Granite Falls
Manson
Sunnybank
Lakeside
Chelan
Wapato Lake
Roses Lake
Columbia River
SKAGIT COUNTY
SNOHOMISH COUNTY
OKANOGAN COUNTY
DOUGLAS COUNTY
LEGEND
WRIA 47 Boundary
Watercourses
Water Bodies
Populated Places
County Boundary
Townships
Sub-basins
Antoine Creek
Drains to Columbia R.
First Creek
Howard Flats
Lucerne Main Stem
Manson Lakes
Railroad Creek
Stehekin
Twenty-five Mile Creek
Wapato Main Stem
0 1.5 3 6
MILES
1 INCH = 1.5 MILES
Drawing is not at original scale if bar is not 4" long.
DATA SOURCES
Ecology Baseflow Stations: Dept. of Ecology, Nov. 2008
Parcels: Chelan County, January 2008
Road: Chelan County, December 2005
Sub-basins: Created by RH2 using ESRI's ArcHydro, June 2008
PLSS Township, Range: Chelan County, July 2008
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2008
DISCLAIMER
This map is a geographic representation based on information available. It does not represent survey data. No warranty is made concerning the accuracy, currency, or completeness of data depicted on this map.



Land Use
WRIA 47 - Lake Chelan
Watershed Planning
Phase II Quantity Assessment
Figure 2-2
Land Use
Chelan County
AC - Comm, Ag
CG - Comm, General
FC - Comm, Forested Lands
MC - Comm, Mineral
CP - Comm, Pedestrian
RC - Comm, Resort
CT - Comm, Tourist
CMA - Airport
P - Public Lands
RI - Industry, Rural
RR2.5 - Rural Res, 2.5 units/acre
RR5 - Rural Res, 5 units/acre
RR10 - Rural Res, 10 units/acre
RR20 - Rural Res, 20 units/acre
RV - Rural Village
UR1 - Urban Res, 1
UR2 - Urban Res, 2
UR3 - Urban Res, 3
RRR - Rural Recreation
RW - Rural Waterfront
UWR - Urban Res, Waterfront
Wapato
UGA
Okanogan County
Single Family Household
Agriculture
Designated Forest Land per RCW 84.33
Irrigated Alfalfa
Range Land
Timber Land per RCW 84.34
Unused Land, or Undeveloped Land
Vacation And Cabin
Vineyards / Grapes
Unknown
LEGEND
WRIA 47 Boundary
Watercourses
Water Bodies
County Boundary
Lake Chelan
Columbia River
0 1.5 3 6
MILES
1 INCH = 1.5 MILES
Drawing is not at original scale if bar is not 4" long.
DATA SOURCES
Land Use, Chelan: Chelan County, Nov. 2008
Land Use, Okanogan: Okanogan County, Nov. 2008
Parcels: Chelan County, January 2008
Road: Chelan County, December 2008
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2008
DISCLAIMER
This map is a geographic representation based on information available. It does not represent survey data. No warranty is made concerning the accuracy, currency, or completeness of data depicted on this map.


PRECIPITATION DISTRIBUTION,
30 YEAR AVERAGE (1961-1990)
WRIA 47 - LAKE CHELAN
WATERSHED PLANNING
PHASE II QUANTITY ASSESSMENT
FIGURE 2-3
Average Annual Precipitation
9"
11"
13"
15"
17"
19"
21"
23"
25"
27"
29"
31"
33"
35"
37"
39"
41"
43"
45"
47"
49"
51"
53"
55"
57"
59"
61"
63"
65"
67"
69"
71"
73"
75"
77"
79"
81"
83"
85"
87"
89"
91"
93"
95"
97"
99"
101"
103"
105"
107"
109"
111"
113"
115"
117"
119"
125"
135"
145"
Environmental Monitoring Stations
SNOTEL Stations
WRCC COOP Stations
LEGEND
WRIA 47 Boundary
Sub-watersheds
Watercourses
Water Bodies
County Boundary
0
1.5
3
6
MILES
1 INCH = 1.5 MILES
Drawing is not at original scale if bar is not 4" long.
Park Creek Ridge
Stehekin
Stehekin 3 NW
Lyman Lake
Holden Village
Holden
Railroad
Lucerne Main Stem
Twentyfive Mile
First Creek
Chelan
150
97A
97
RH2

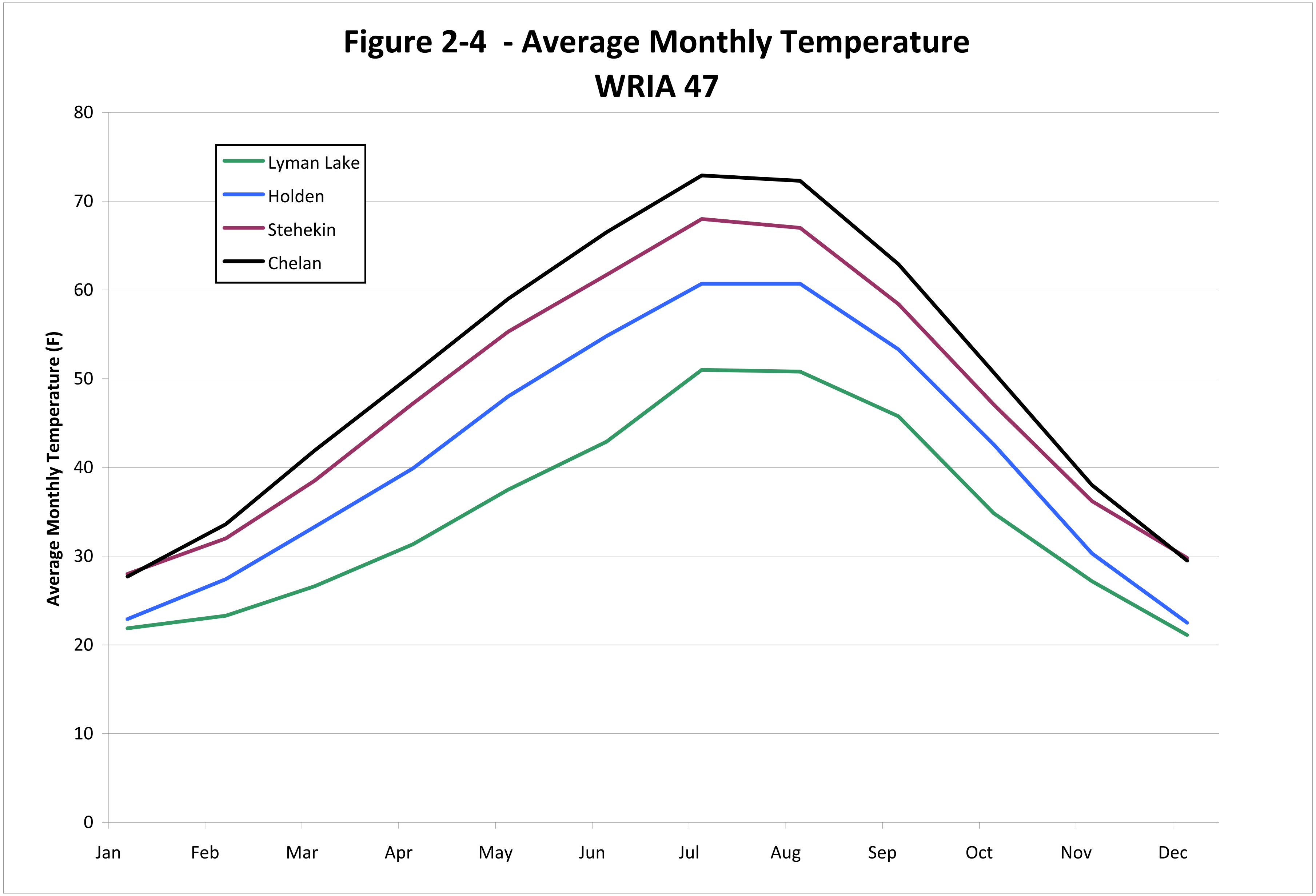


Figure 2-4 - Average Monthly Temperature
WRIA 47
Average Monthly Temperature (F)
Lyman Lake
Holden
Stehekin
Chelan
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

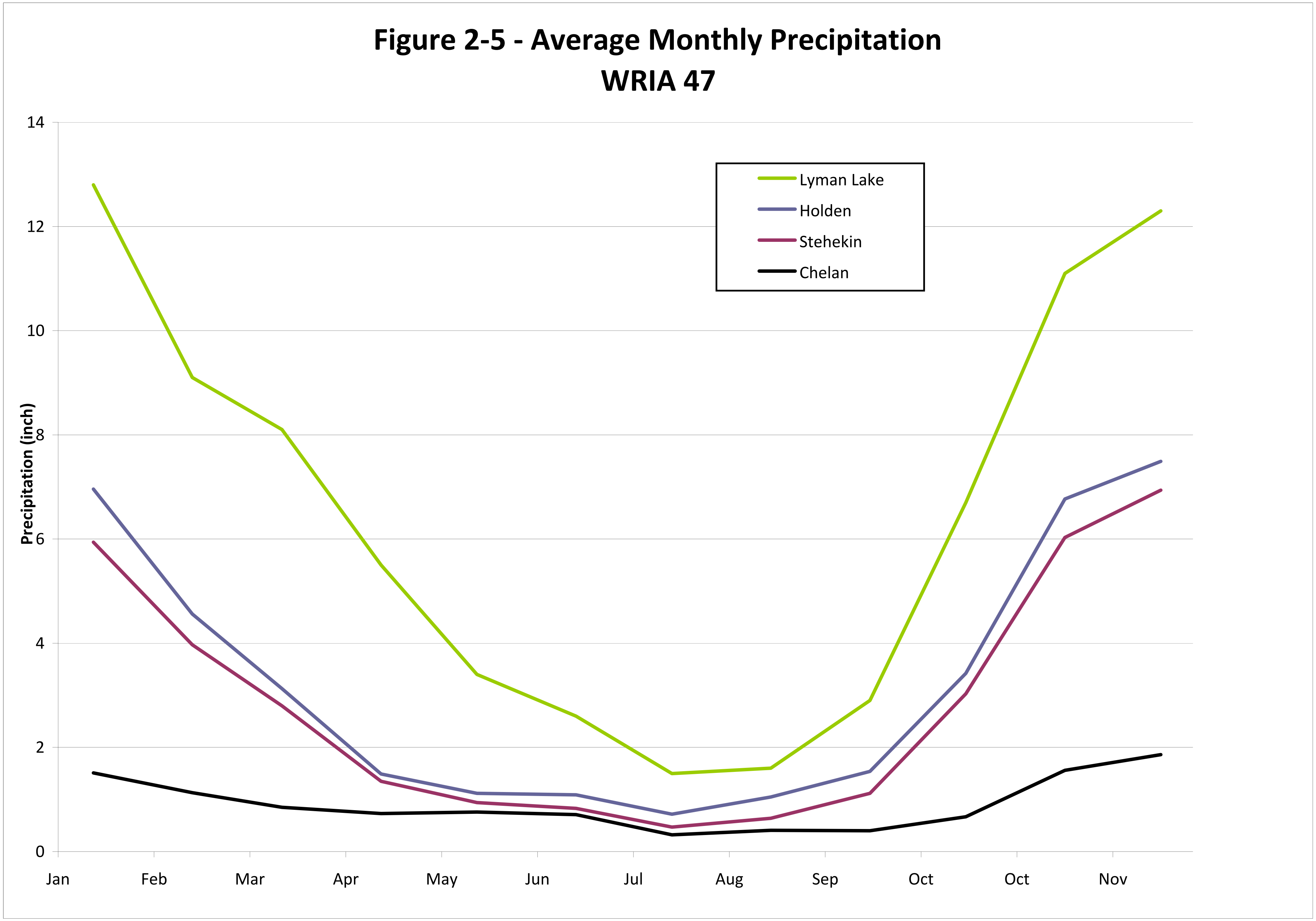


Figure 2-5 - Average Monthly Precipitation
WRIA 47
Precipitation (inch)
0
2
4
6
8
10
12
14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Oct
Nov
Lyman Lake
Holden
Stehekin
Chelan

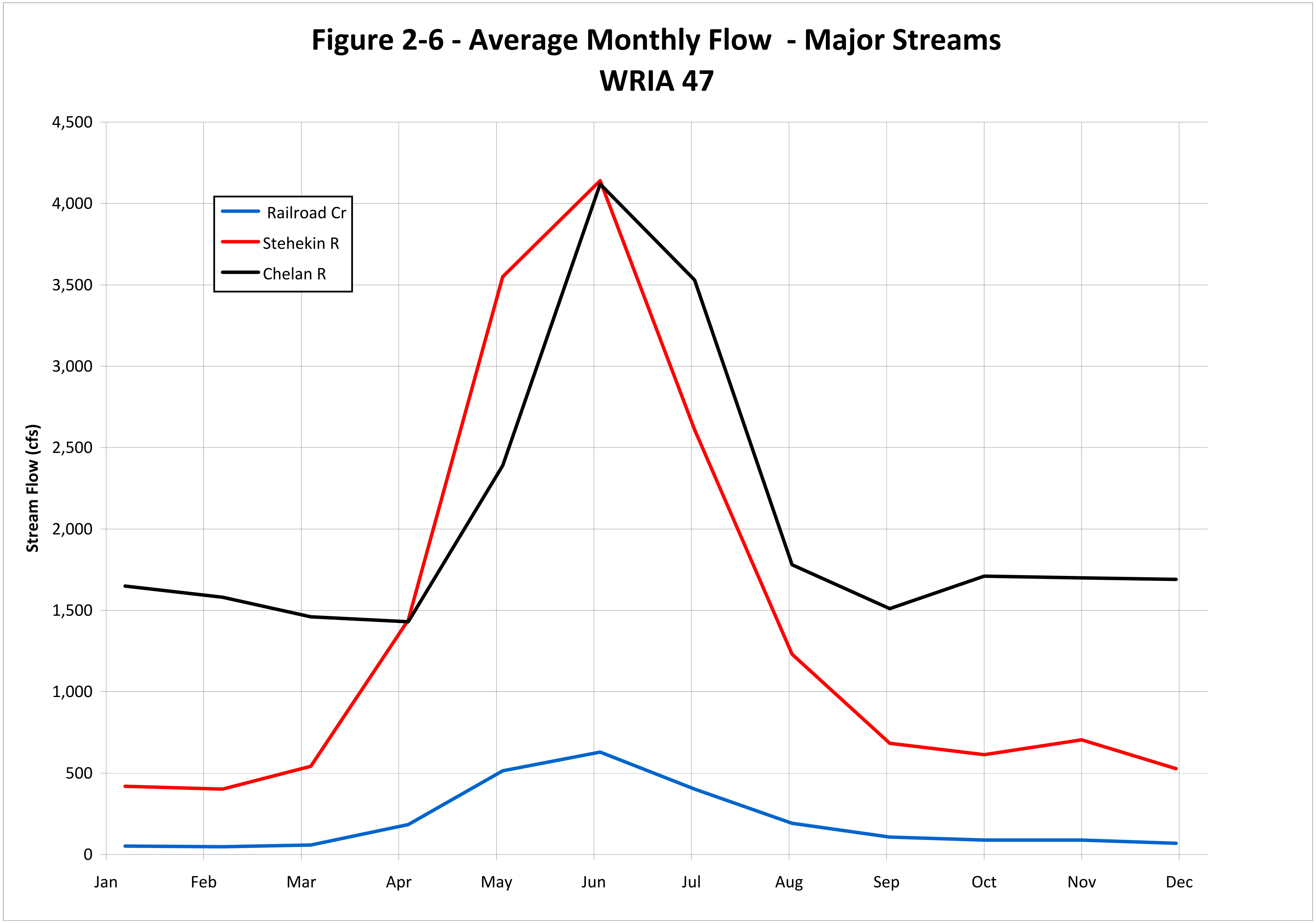


Figure 2-6 - Average Monthly Flow - Major Streams
WRIA 47
Railroad Cr
Stehekin R
Chelan R
Stream Flow (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

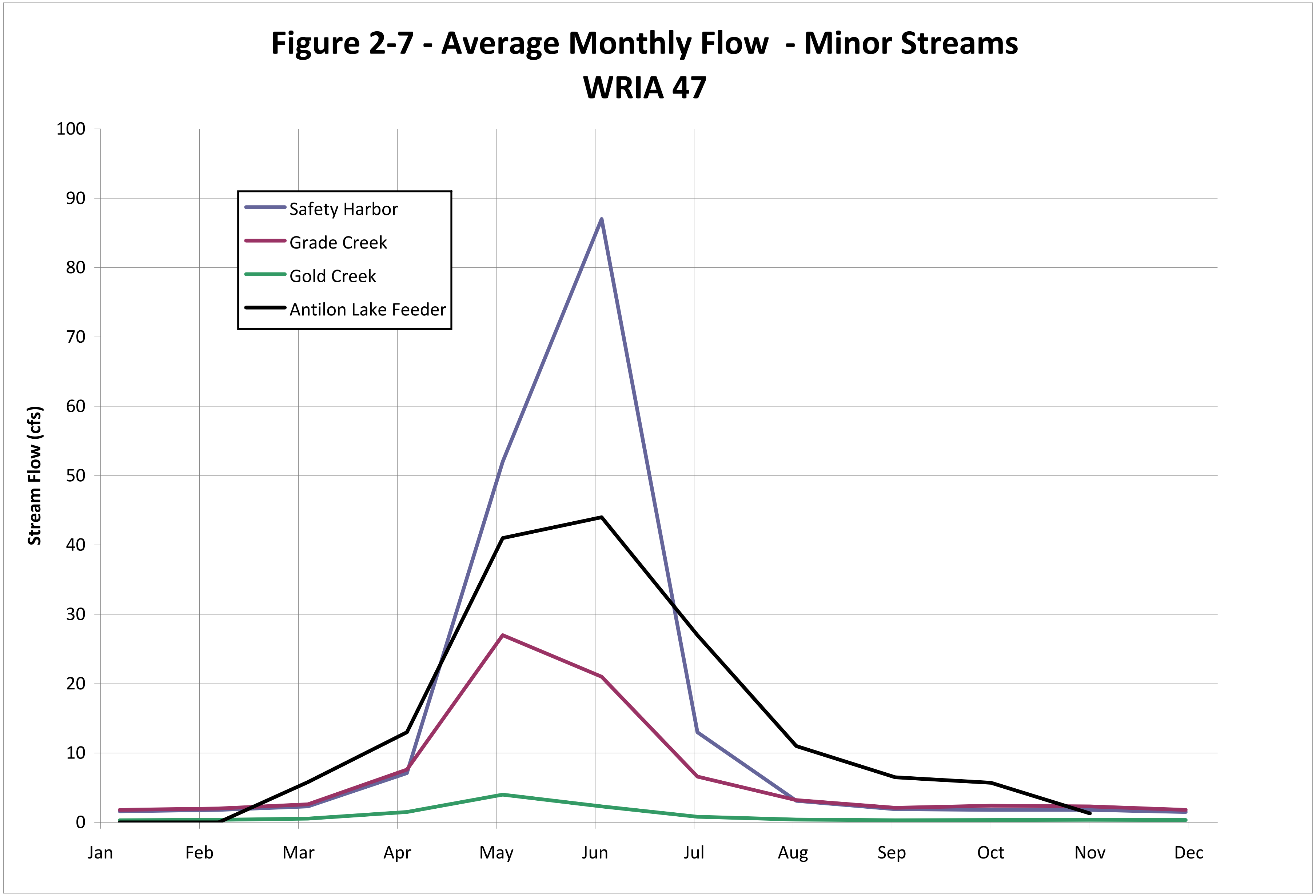


Figure 2-7 - Average Monthly Flow - Minor Streams
WRIA 47
Stream Flow (cfs)
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Safety Harbor
Grade Creek
Gold Creek
Antilon Lake Feeder

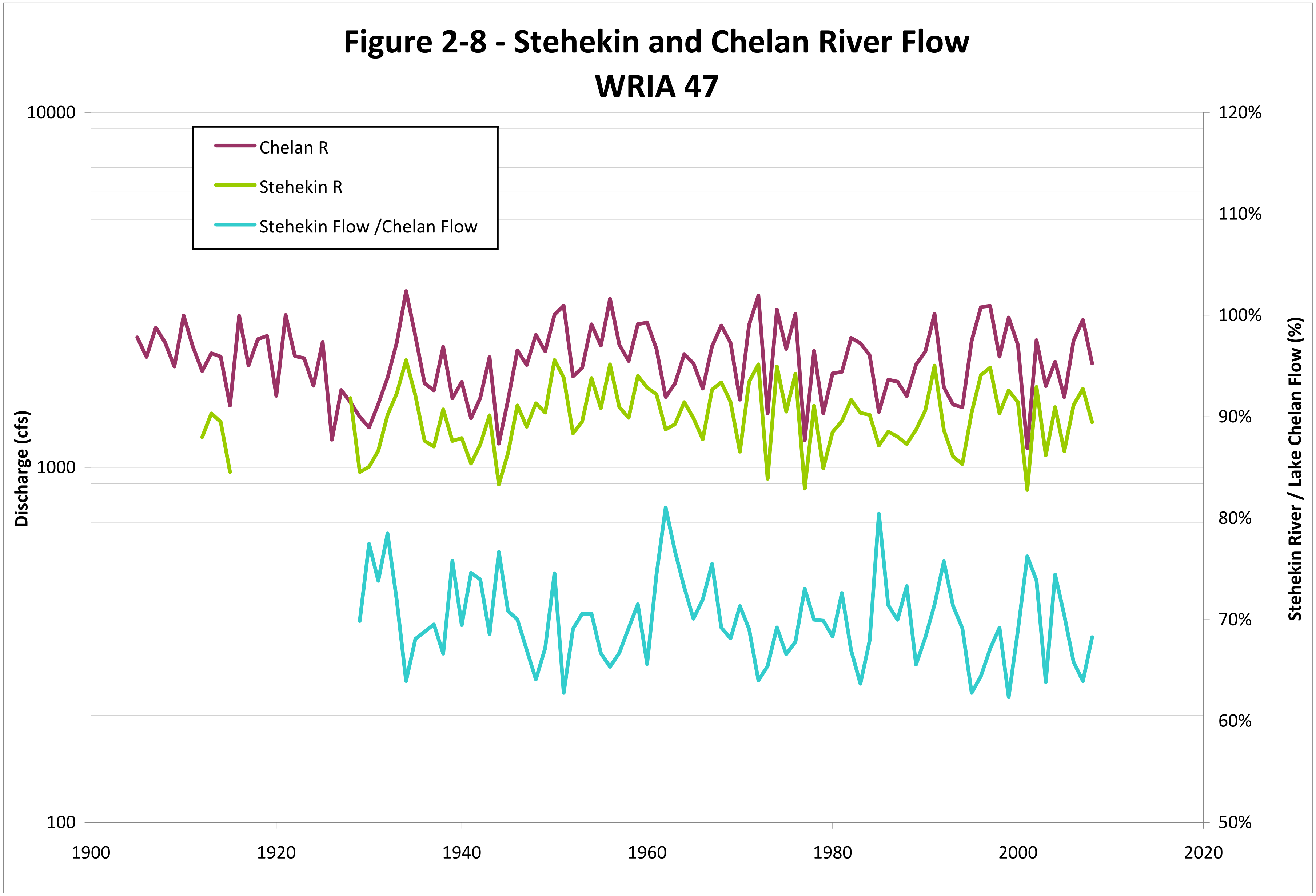


Figure 2-8 - Stehekin and Chelan River Flow
WRIA 47
Chelan R
Stehekin R
Stehekin Flow /Chelan Flow
Discharge (cfs)
10000
1000
100
1900
1920
1940
1960
1980
2000
2020
Stehekin River / Lake Chelan Flow (%)
120%
110%
100%
90%
80%
70%
60%
50%

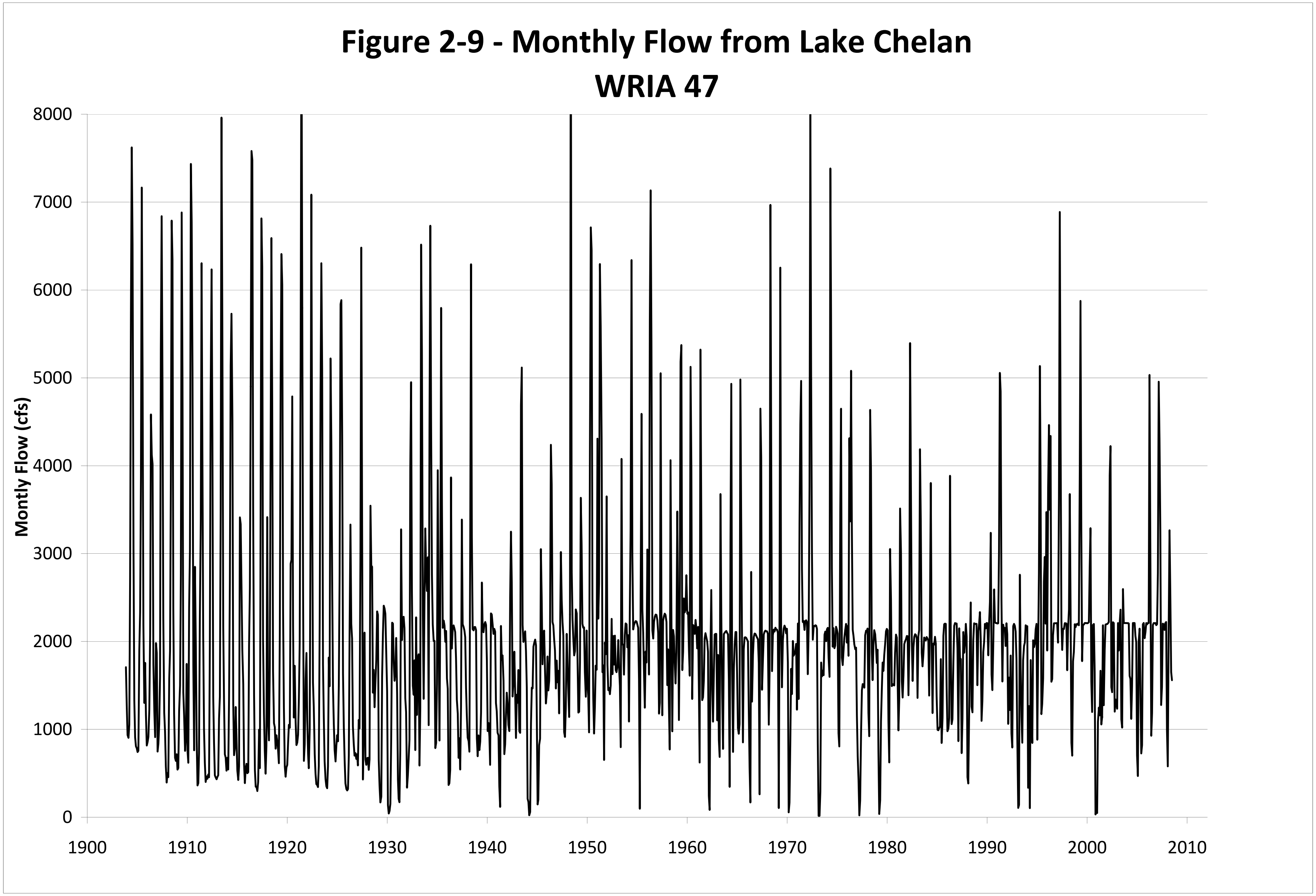


Figure 2-9 - Monthly Flow from Lake Chelan
WRIA 47
Montly Flow (cfs)
0
1000
2000
3000
4000
5000
6000
7000
8000
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

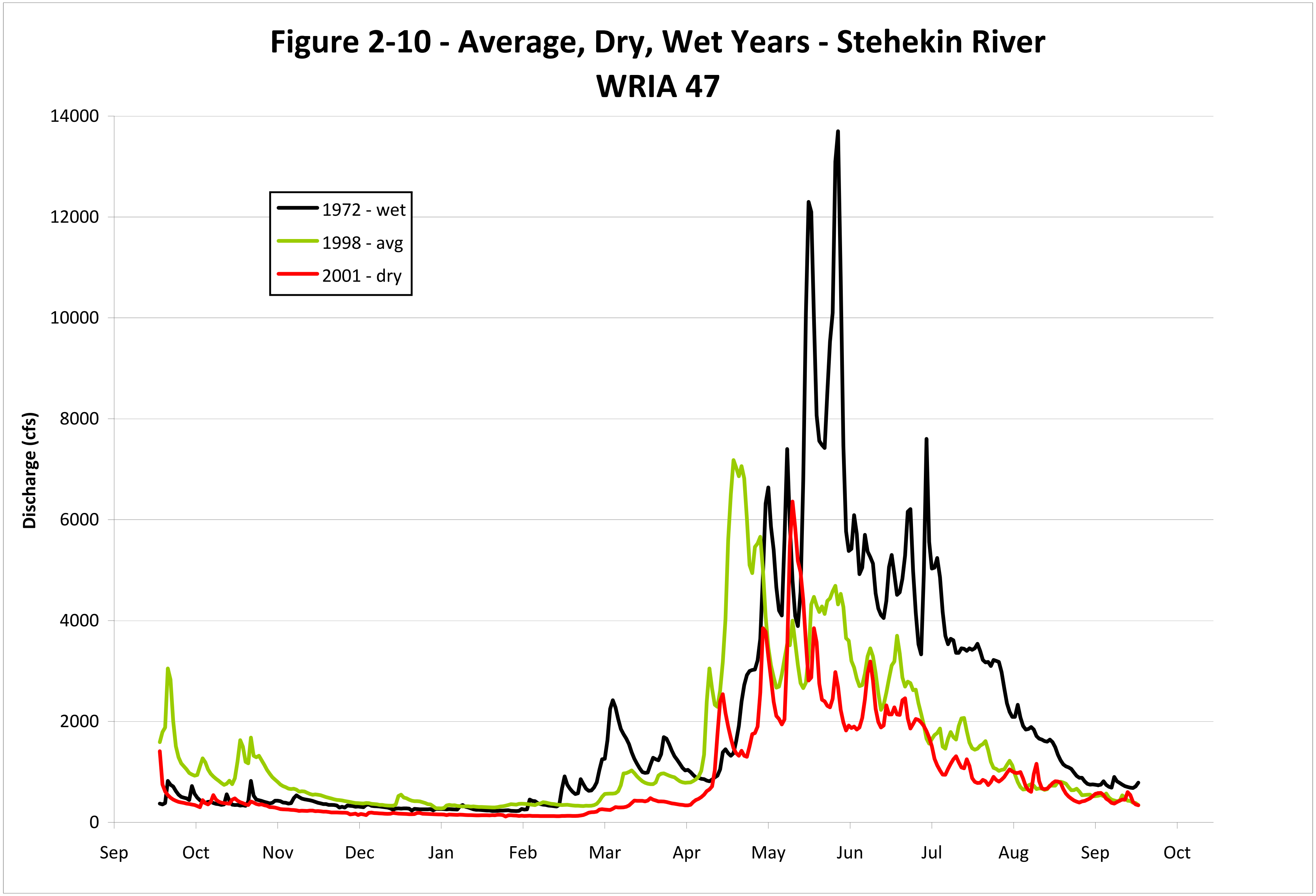


Figure 2-10 - Average, Dry, Wet Years - Stehekin River
WRIA 47
1972 - wet
1998 - avg
2001 - dry
Discharge (cfs)
14000
12000
10000
8000
6000
4000
2000
0
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

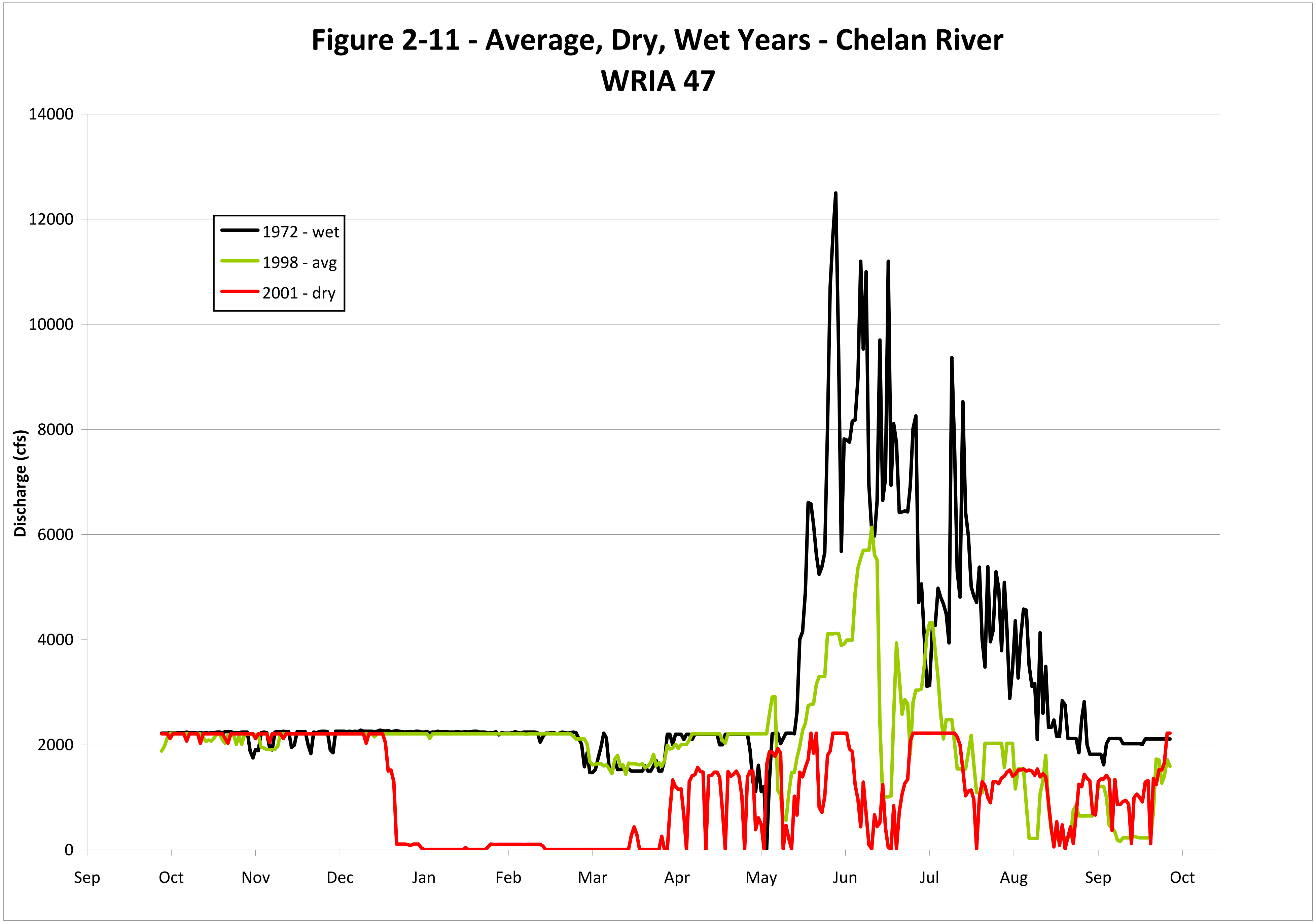


Figure 2-11 - Average, Dry, Wet Years - Chelan River
WRIA 47
1972 - wet
1998 - avg
2001 - dry
Discharge (cfs)
14000
12000
10000
8000
6000
4000
2000
0
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

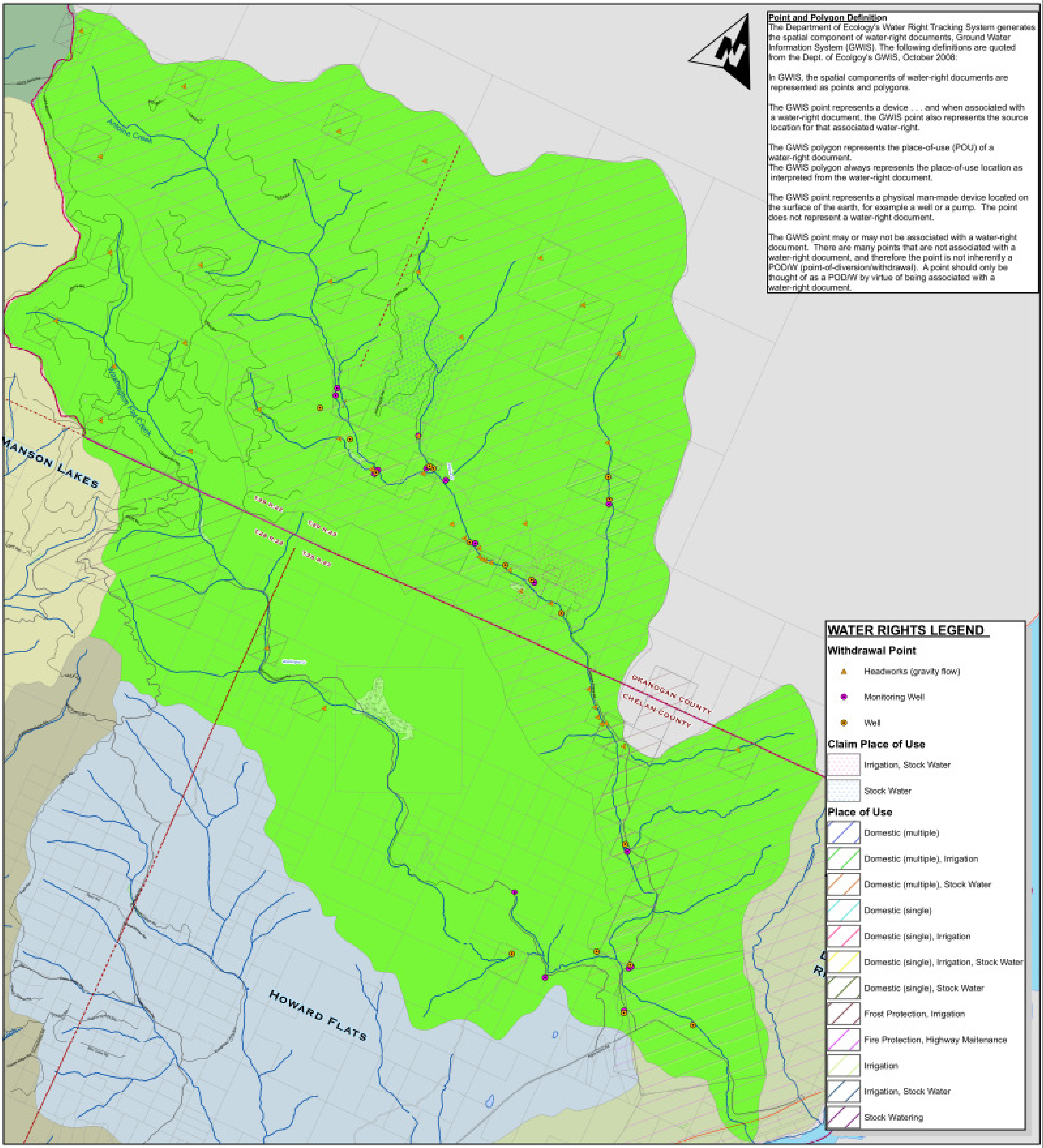


Figure 3-1. Antoine Creek Sub-Basin

Place of Use: Point of Withdrawals & Water-Right Boundary Polygons

WRIA 47 - Lake Chelan

Watershed Planning

Phase II Quantity Assessment

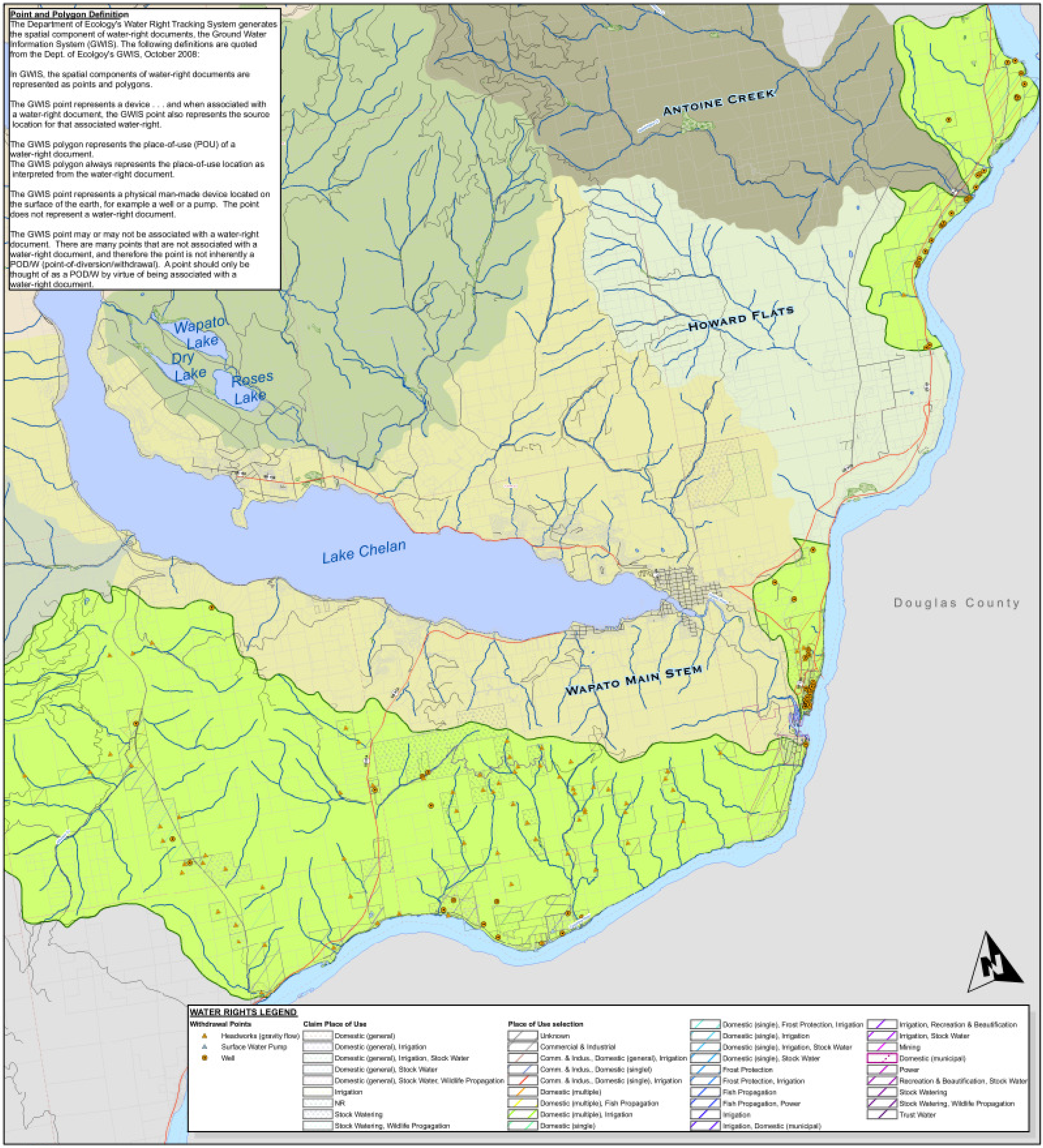


Figure 3-2. Direct Drainage to Columbia River

Point of Withdrawals and Water-right Documents Listed Purpose

WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment

0 0.25 0.5
Miles
1 INCH = 0.5 MILES

LEGEND
Parcels
Township, Range
Roads
Highways
Water Courses
Wetlands
Waterbodies

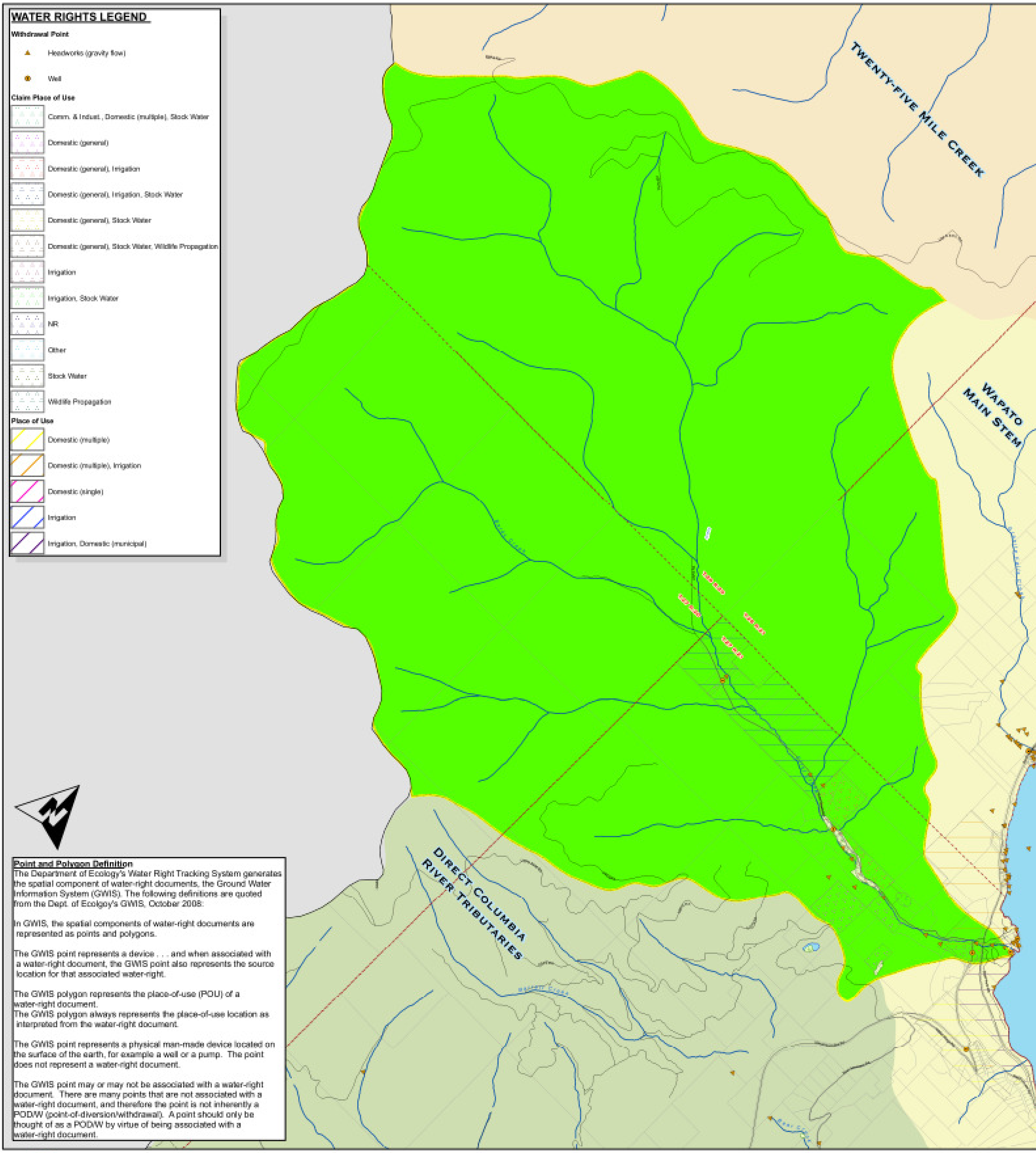


Figure 3-3. First Creek Sub-Basin

Place of Use: Point of Withdrawals & Water-Right Boundary Polygons

WRIA 47 - Lake Chelan

Watershed Planning

Phase II Quantity Assessment

0 0.2 0.4 Miles

1 INCH = 1,056 Feet

1 INCH = 0.2 MILES

LEGEND
- Parcels
- Township, Range
- Roads
- Highways
- Water Courses
- Waterbodies
- Wetlands

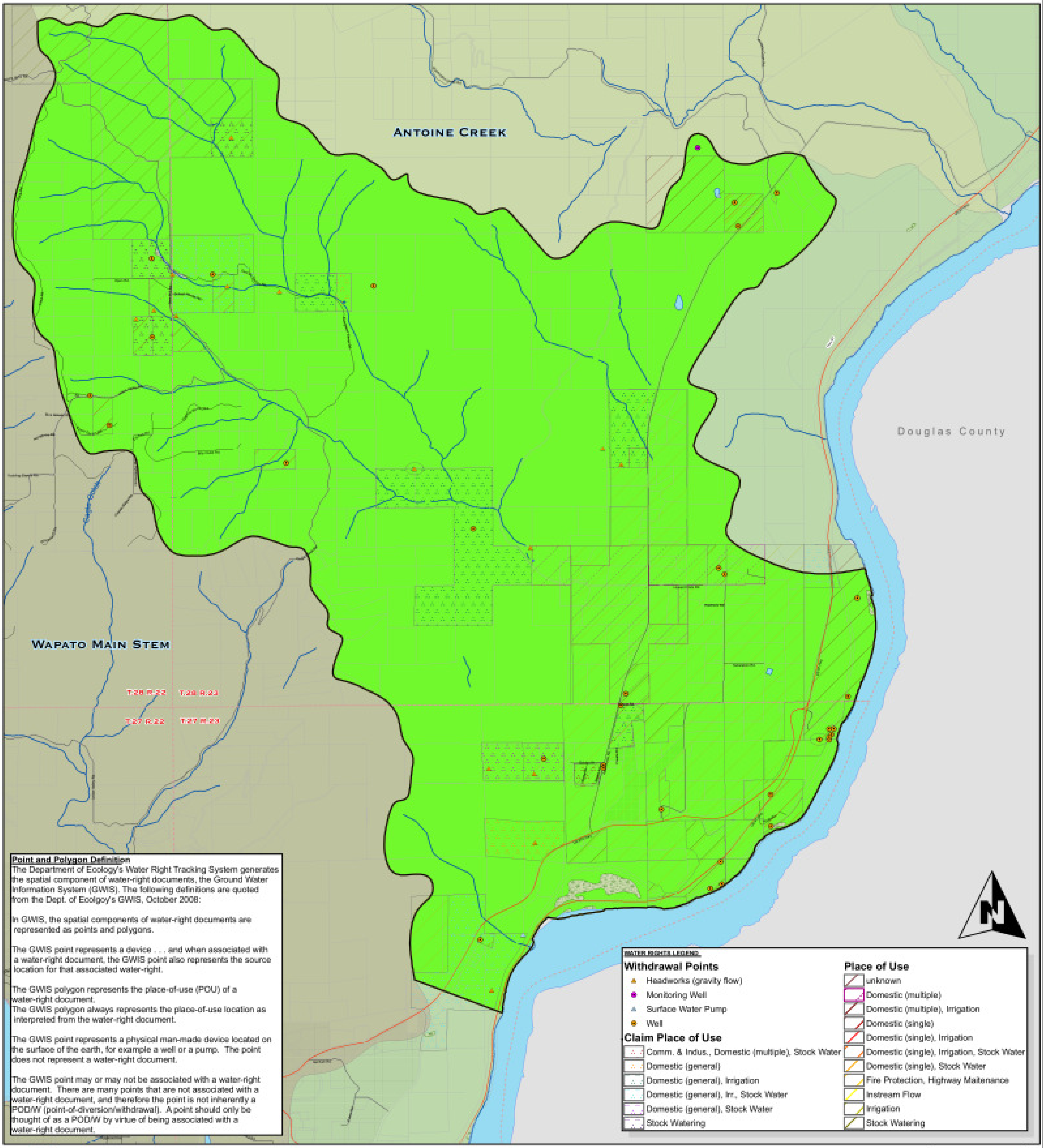


Figure 3-4. Howard Flats Sub-Basin

Place of Use: Point of Withdrawals & Water-Right Boundary Polygons

WRIA 47 - Lake Chelan

Watershed Planning

Phase II Quantity Assessment

0 0.2 0.4 Miles

1 INCH = 0.2 MILES

LEGEND
- Parcels
- Township, Range
- City of Chelan
- Roads
- Highway
- Water Courses
- Waterbodies
- Wetlands

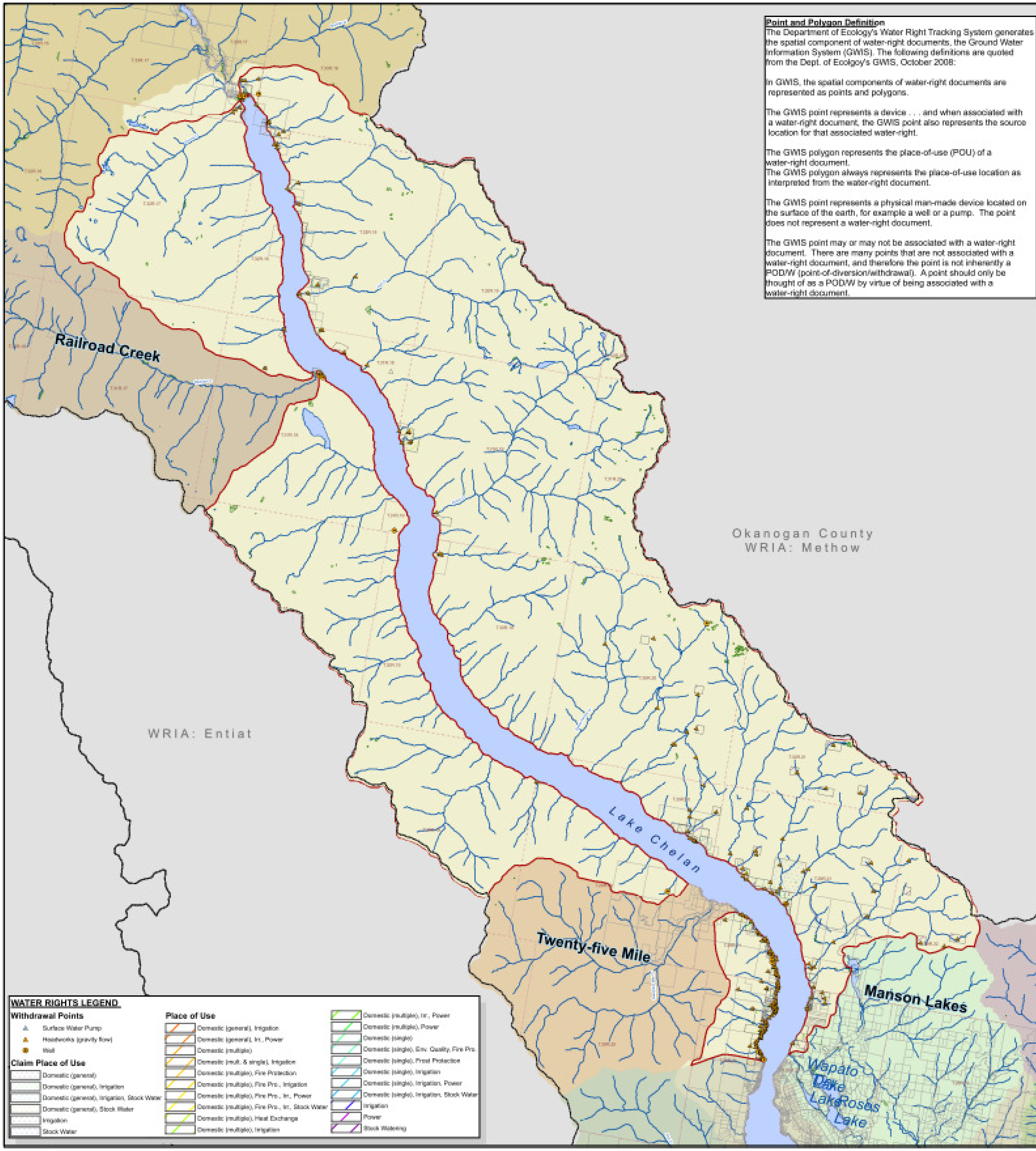


Figure 3-5. Lucerne Main Stem Sub-Basin

Point of Withdrawals and Water-right Documents Listed Purpose

WRIA 47 - Lake Chelan Watershed Planning

Phase II Quantity Assessment

0 1 2 Miles

1 INCH = 1 MILES

LEGEND

Parcels

Township, Range

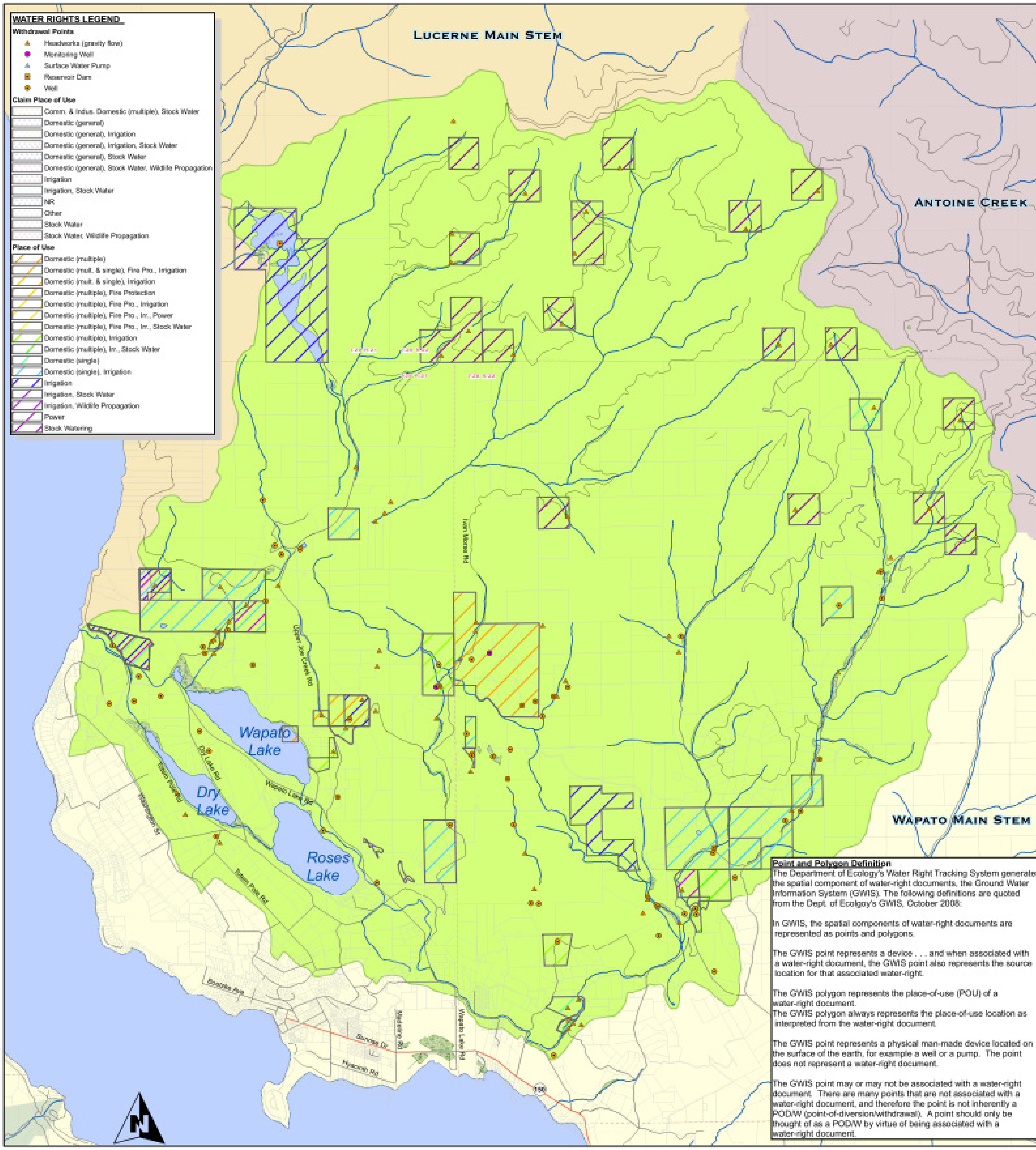
Roads

Highway

Water Courses

Wetlands

Waterbodies



Point and Polygon Definition

The Department of Ecology's Water Right Tracking System generates the spatial component of water-right documents, the Ground Water Information System (GWIS). The following definitions are quoted from the Dept. of Ecolgoy's GWIS, October 2008:

In GWIS, the spatial components of water-right documents are represented as points and polygons.

The GWIS point represents a device . . . and when associated with a water-right document, the GWIS point also represents the source location for that associated water-right.

The GWIS polygon represents the place-of-use (POU) of a water-right document.
The GWIS polygon always represents the place-of-use location as interpreted from the water-right document.

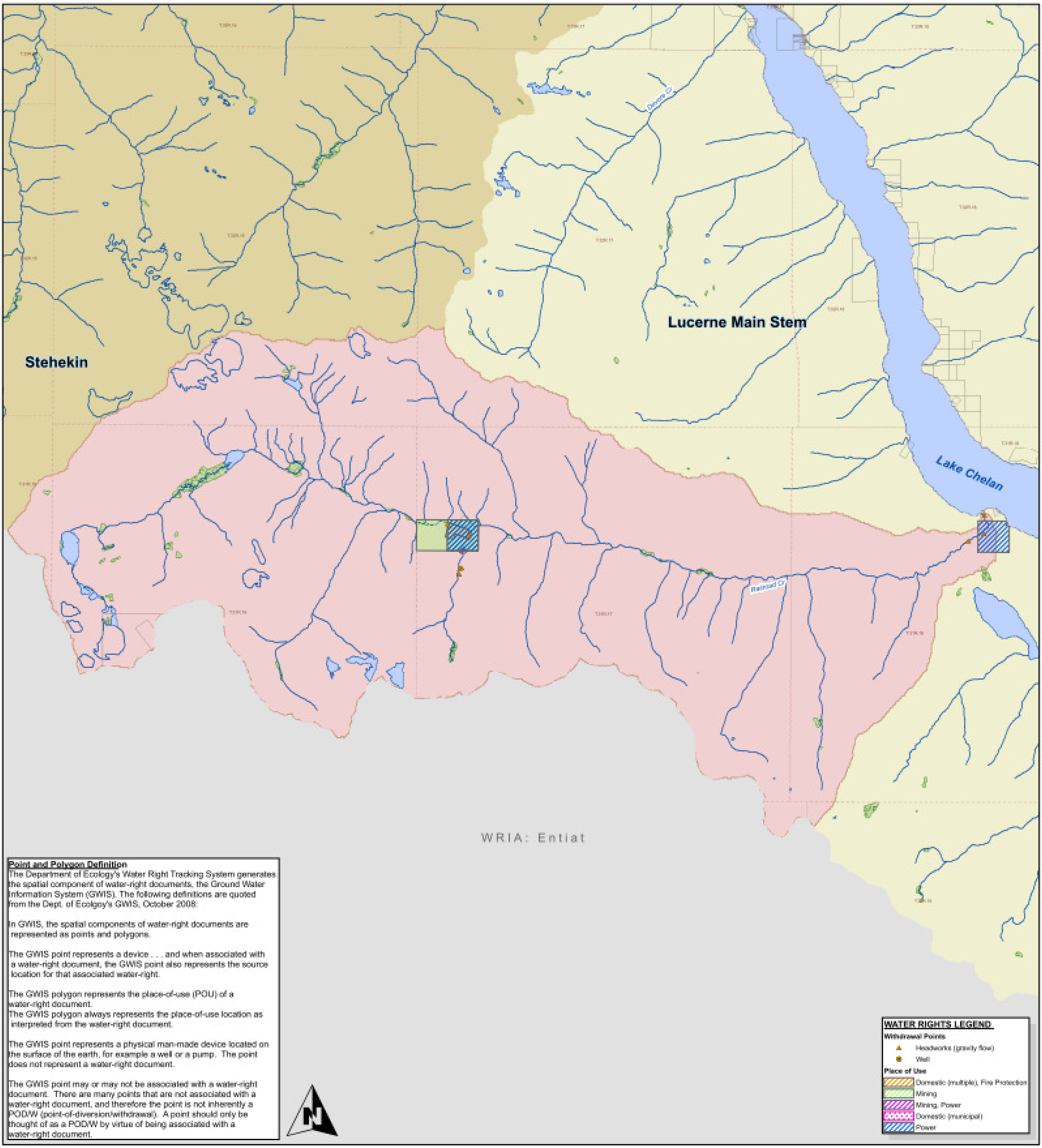
The GWIS point represents a physical man-made device located on the surface of the earth, for example a well or a pump. The point does not represent a water-right document.

The GWIS point may or may not be associated with a water-right document. There are many points that are not associated with a water-right document, and therefore the point is not inherently a POD/W (point-of-diversion/withdrawal). A point should only be thought of as a POD/W by virtue of being associated with a water-right document.

Figure 3-6. Manson Lakes Sub-Basin
Point of Withdrawals and Water-right Documents Listed Purpose
WRIA 47 - Lake Chelan Watershed Planning
Phase II Quantity Assessment

0 0.25 0.5 Miles

1 INCH = 0.25 MILES



Point and Polygon Definition

The Department of Ecology's Water Right Tracking System generates the spatial component of water-right documents, the Ground Water Information System (GWIS). The following definitions are quoted from the Dept. of Ecolgoy's GWIS, October 2008:

In GWIS, the spatial components of water-right documents are represented as points and polygons.

The GWIS point represents a device . . . and when associated with a water-right document, the GWIS point also represents the source location for that associated water-right.

The GWIS polygon represents the place-of-use (POU) of a water-right document.
The GWIS polygon always represents the place-of-use location as interpreted from the water-right document.

The GWIS point represents a physical man-made device located on the surface of the earth, for example a well or a pump. The point does not represent a water-right document.

The GWIS point may or may not be associated with a water-right document. There are many points that are not associated with a water-right document, and therefore the point is not inherently a POD/W (point-of-diversion/withdrawal). A point should only be thought of as a POD/W by virtue of being associated with a water-right document.

Figure 3-7. Railroad Creek Sub-Basin

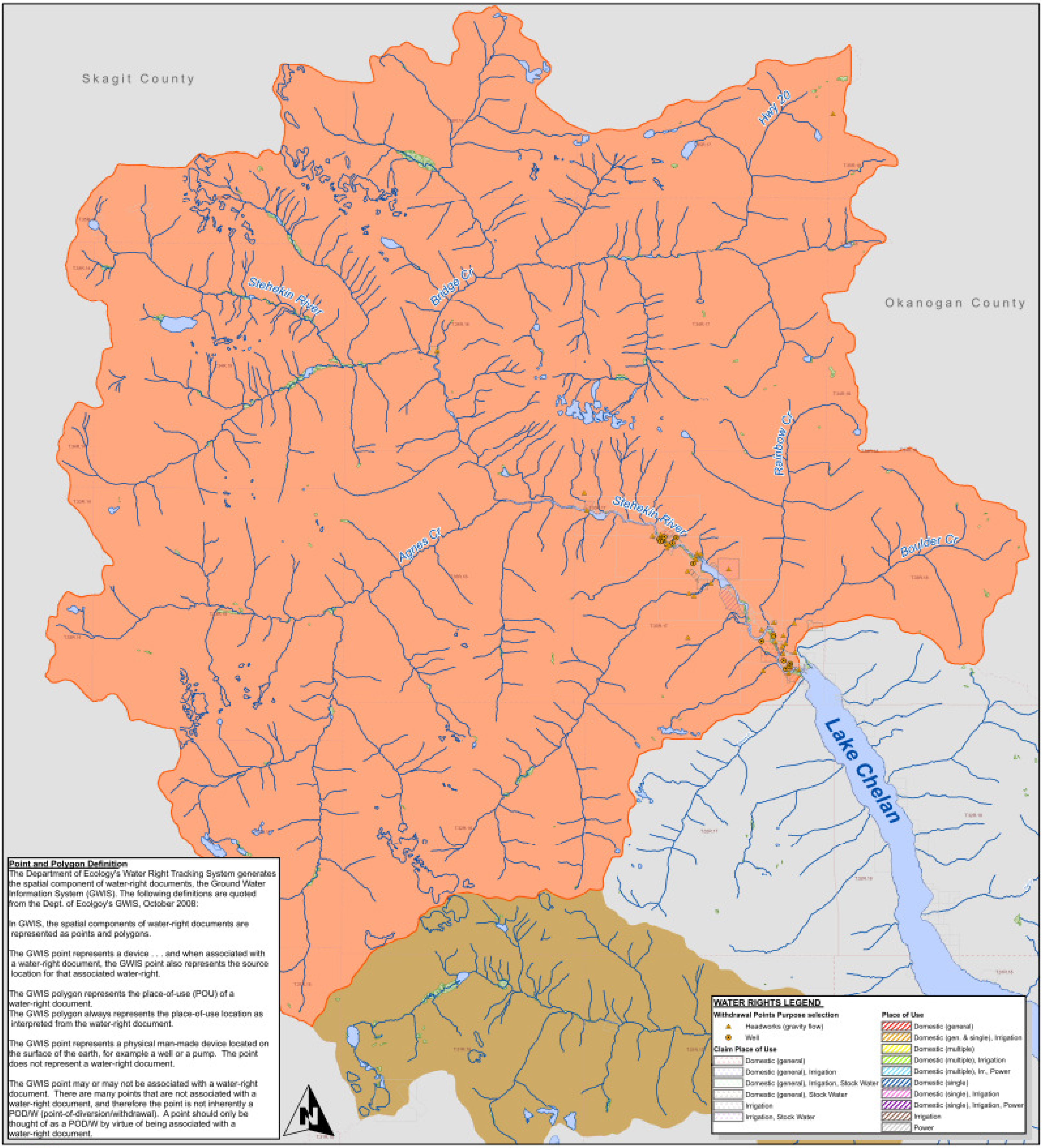
Point of Withdrawals and Water-right Documents Listed Purpose
WRIA 47 - Lake Chelan Watershed Planning
Phase II Quantity Assessment

0 0.5 1 Miles

1 INCH = 0.5 MILES

LEGEND

- Parcels
- Township, Range
- Roads
- Highway
- Water Courses
- Wetlands
- Waterbodies



Point and Polygon Definition

The Department of Ecology's Water Right Tracking System generates the spatial component of water-right documents, the Ground Water Information System (GWIS). The following definitions are quoted from the Dept. of Ecolgoy's GWIS, October 2008:

In GWIS, the spatial components of water-right documents are represented as points and polygons.

The GWIS point represents a device . . . and when associated with a water-right document, the GWIS point also represents the source location for that associated water-right.

The GWIS polygon represents the place-of-use (POU) of a water-right document.
The GWIS polygon always represents the place-of-use location as interpreted from the water-right document.

The GWIS point represents a physical man-made device located on the surface of the earth, for example a well or a pump. The point does not represent a water-right document.

The GWIS point may or may not be associated with a water-right document. There are many points that are not associated with a water-right document, and therefore the point is not inherently a POD/W (point-of-diversion/withdrawal). A point should only be thought of as a POD/W by virtue of being associated with a water-right document.

Figure 3-8. Stehekin Sub-Basin

Point of Withdrawals and Water-right Documents Listed Purpose

WRIA 47 - Lake Chelan Watershed Planning

Phase II Quantity Assessment

0 0.75 1.5 Miles

1 INCH = 0.75 MILES

LEGEND

- Parcels
- Township, Range
- Roads
- Highway
- Water Courses
- Wetlands
- Waterbodies

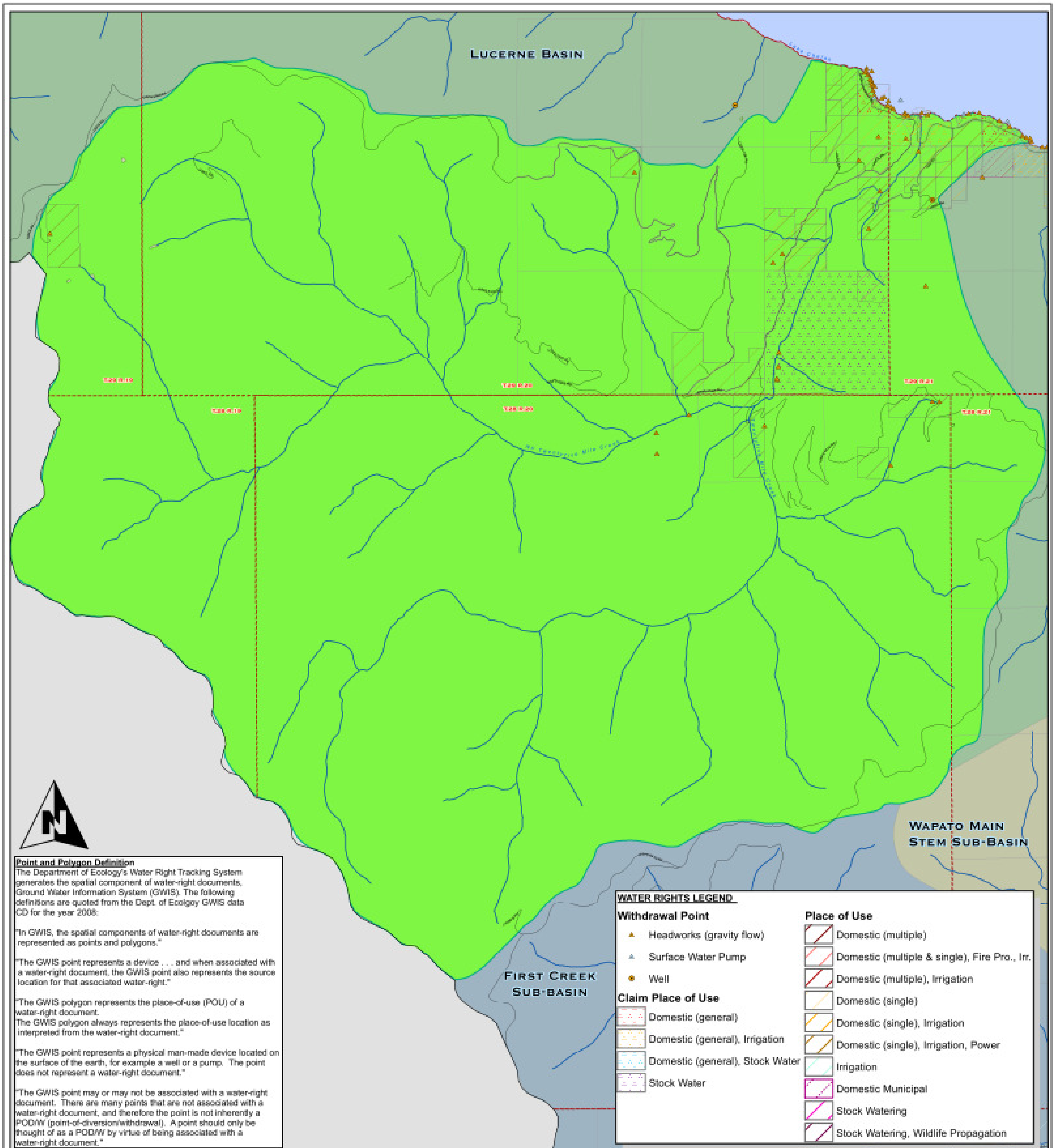


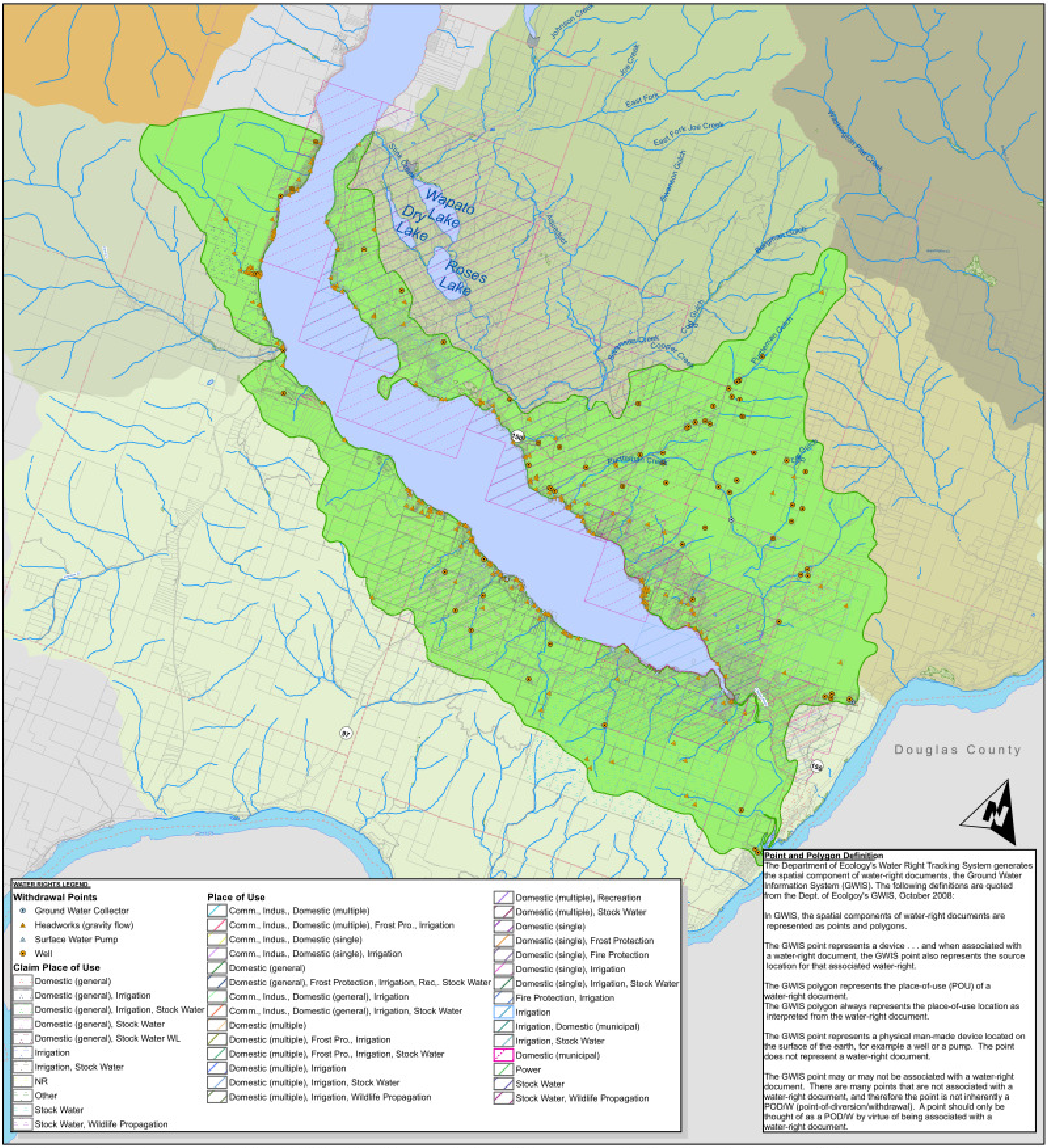
Fig. 3-9. Twenty-five Mile Creek Sub-Basin

Place of Use: Point of Withdrawals & Water-Right Boundary Polygons

WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment

0 0.25 0.5 Miles
1 INCH = 0.25 MILES
1 INCH = 1,320 FEET

LEGEND
Parcels
Township, Range
Roads
Highways
Water Courses
Waterbodies
Wetlands



Point and Polygon Definition

The Department of Ecology's Water Right Tracking System generates the spatial component of water-right documents, the Ground Water Information System (GWIS). The following definitions are quoted from the Dept. of Ecolgoy's GWIS, October 2008:

In GWIS, the spatial components of water-right documents are represented as points and polygons.

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The GWIS polygon always represents the place-of-use location as interpreted from the water-right document.

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The GWIS point may or may not be associated with a water-right document. There are many points that are not associated with a water-right document, and therefore the point is not inherently a POD/W (point-of-diversion/withdrawal). A point should only be thought of as a POD/W by virtue of being associated with a water-right document.

Figure 3-10. Wapato Main Stem Sub-Basin

Point of Withdrawals and Listed Purpose With Water-rights Document WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment

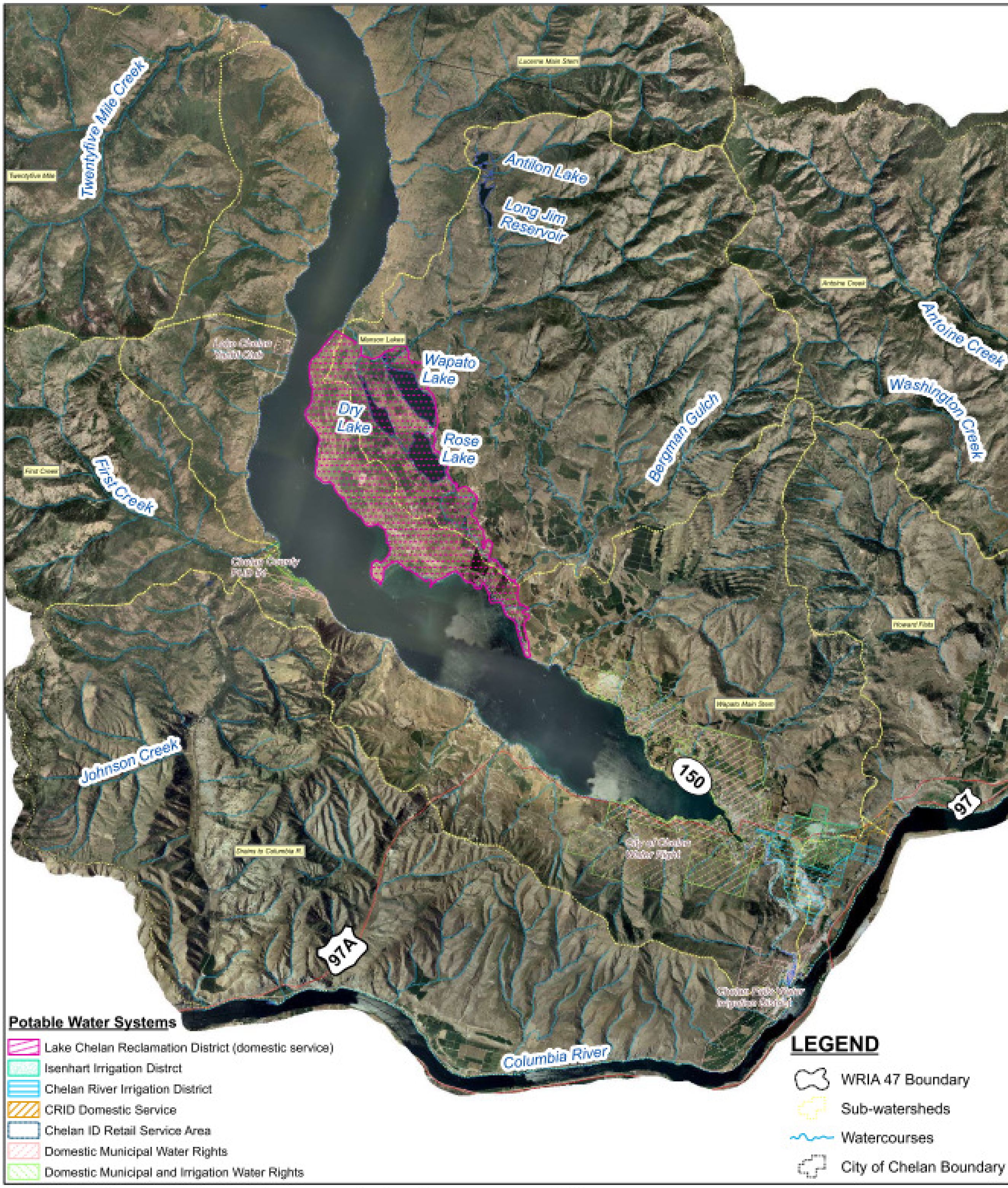
RH2

0 0.5 1 Miles

1 INCH = 0.5 MILES

LEGEND

- Parcels
- Township, Range
- Roads
- Highway
- Water Courses
- Waterbodies
- Wetlands

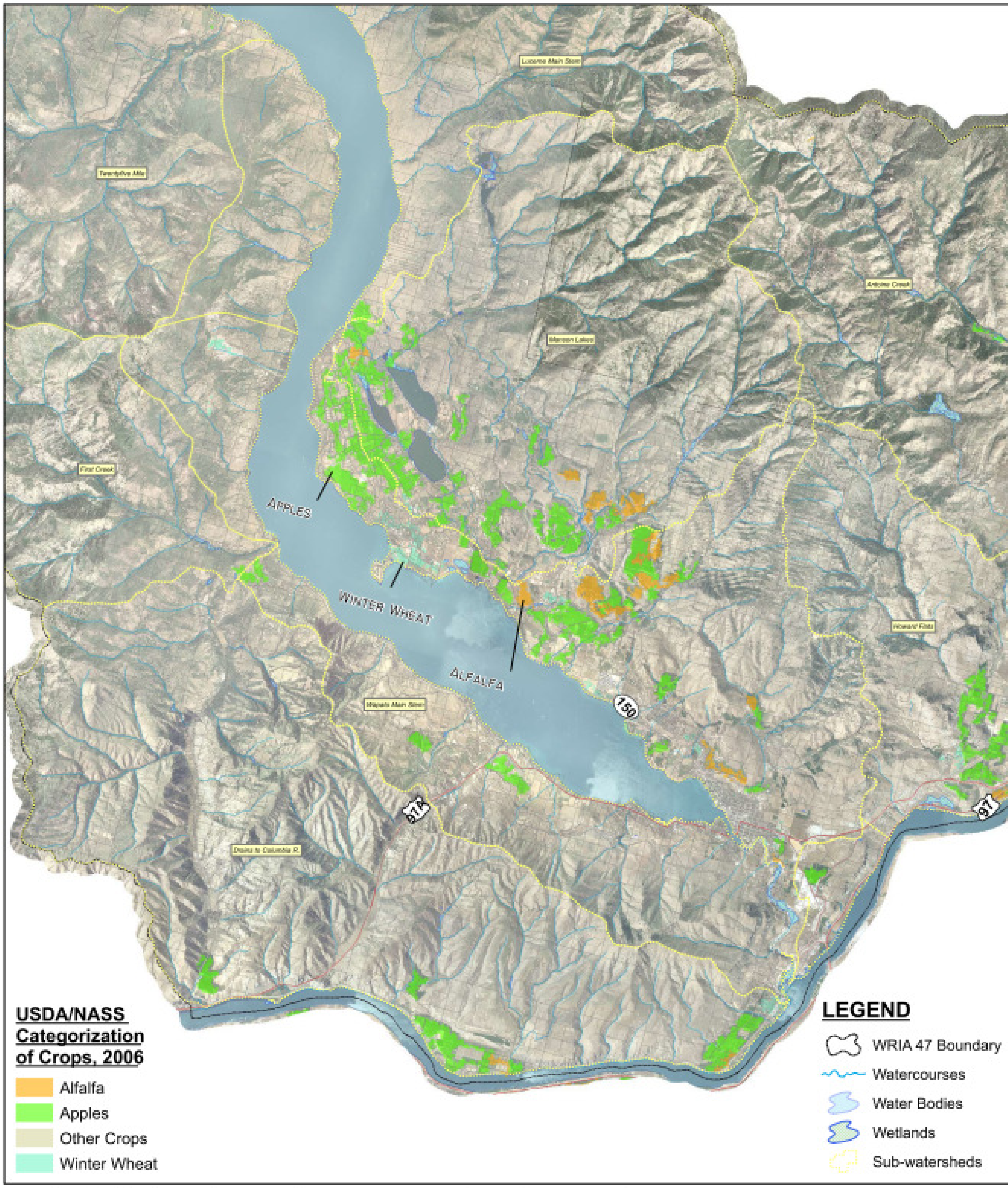


0 0.5 1 2
MILES
1 INCH = 0.5 MILES
Drawing is not at original scale if bar is not 4" long.

DATA SOURCES
Aerial Imagery: USDA, NAIP, Hosted by U. of W. 2006
Highways: Dept. of Transportation, 2008
LCRD: Lake Chelan Reclamation District, Feb. 2008
Potable Water Systems: Dept. of Ecology Water Resources Program, 2008
Road: Chelan County, December 2008
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2000

Figure 4-1. Potable Water Systems
WRIA 47 - Lake Chelan
Watershed Planning
Phase II Quantity Assessment

DISCLAIMER
This map is a geographic representation based on information available. It does not represent survey data. No warranty is made concerning the accuracy, currency, or completeness of data depicted on this map.

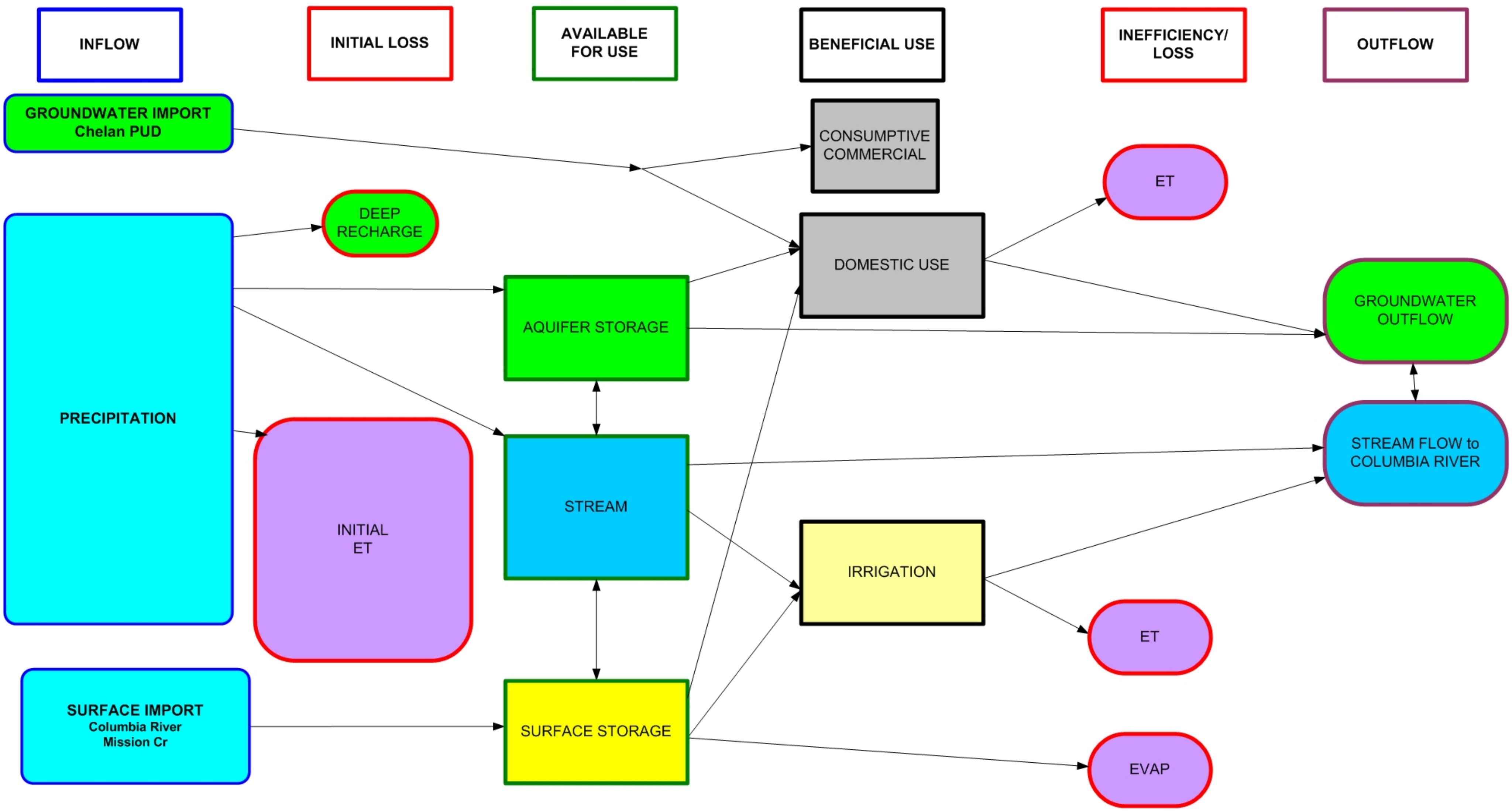


0 0.5 1 2
MILES
1 INCH = 0.5 MILES
Drawing is not at original scale if bar is not 4" long.

Figure 4-2. Crop Cover

WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment

Figure 5-1
Water Balance Schematic



Appendix B
Water Quality Assessment Documents

Long-Term Monitoring Plan for Lake Chelan
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Submitted to:
Chelan County Natural Resource Department, Wenatchee, WA

Submitted by:
AMEC Geomatrix, Inc., Lynnwood, WA

June 2009

Project 13462.002

AMEC Geomatrix

TABLE OF CONTENTS

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TABLES

FIGURE

APPENDICES

ACRONYMS AND ABBREVIATIONS

BOD	biological oxygen demand
BMP	best management practice
CBOD	carbonaceous biological oxygen demand
DO	dissolved oxygen
DOC	dissolved organic carbon
DOM	dissolved organic matter
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
LTMP	long-term monitoring plan
NTR	National Toxic Rule
PCB	polychlorinated biphenyl
POC	particulate organic carbon
POM	particulate organic matter
RCW	Revised Code of Washington
SPMD	semipermeable membrane device
TOC	total organic carbon
TMDL	total maximum daily load
TSS	total suspended solids
WRIA	Water Resource Inventory Area

LONG-TERM MONITORING PLAN FOR LAKE CHELAN

WRIA 47 Phase II Watershed Planning
Chelan County, Washington

EXECUTIVE SUMMARY

On May 14, 2008, the Water Resource Inventory Area (WRIA) 47 Water Quality Subcommittee met to discuss future objectives for assessing water quality in Lake Chelan. The Subcommittee approved a recommendation to develop and implement a long-term monitoring plan (LTMP) for the lake. This document summaries the recommendations and ideas proposed by Subcommittee members for the development of a LTMP and provides an initial framework for the plan that focuses on the calibration and application of two models (CE-QUAL-W2 and the Lake Chelan food web model). These models will allow the evaluation of water quality dealing with water clarity, eutrophication, and toxics accumulation in fish tissue.

LONG-TERM MONITORING PLAN FOR LAKE CHELAN

WRIA 47 Phase II Watershed Planning
Chelan County, Washington

1.0 INTRODUCTION

The Lake Chelan Watershed Planning Unit was created in 2007 to conduct comprehensive watershed planning under Washington State's Watershed Planning Act (Chapter 90.82 RCW). Phase I of the watershed planning process (organization) was completed in January of 2008 (RH2 and Geomatrix, 2008). These activities included identifying all WRIA 47 waterbodies with potentially impaired water quality and identification of the parameters currently on the Clean Water Act 303(d) list (Appendix A). In addition, information collected in all water quality studies conducted in Water Resource Inventory Area (WRIA) 47 since 1972 were reviewed to identify data gaps and to assess whether existing data was sufficient to be able to detect trends in water quality (Appendix B).

Existing water quality concerns within WRIA 47 include elevated fish tissue concentrations of organochlorine pesticides (alpha-BHC, chlordane, DDT, DDE, DDD, and dieldrin), polychlorinated biphenyls (PCBs), and dioxins/furans. In addition, some waterbodies have water quality concerns as a result of elevated total phosphorus concentrations, pH, dissolved oxygen, and the presence of invasive exotic plants. A review of the existing information shows that while a large list of conventional water quality parameters and toxics have been measured in WRIA 47 waterbodies over the last 35 years, there are relatively few parameters that have been consistently measured by the studies. The lack of consistent methods, monitoring stations, and varying frequency of sampling events makes it difficult to assess trends in water quality within WRIA 47.

In May 2008, the WRIA 47 Water Quality Subcommittee (Subcommittee) met to discuss future objectives for assessing water quality in WRIA 47. Water quality issues with the WRIA fall into the three categories listed below:

- Identified impaired water quality and no total maximum daily load (TMDL) has been completed (Lake Chelan for alpha-BHC, chlordane, dieldrin, and dioxin).

- Identified impaired water quality. A TMDL has been completed and a Detailed Implementation Plan is being implemented to address water quality concerns (Lake Chelan for DDT, DDE, DDD, total PCB, total phosphorus; Chelan River for DDT, DDE, DDD, and Roses Lake for DDE).

- Available data suggests that not all beneficial uses for the waterbody may be supported; however, the data is insufficient to list the waterbody as having impaired water quality (Anton, Dry, Roses, and Wapato lakes for total phosphorus; Chelan River for temperature; First Creek for dissolved oxygen; and Wapato Lake for dieldrin).

Of the waterbodies with known water quality concerns, Lake Chelan was the only one that is considered to have impaired water quality and a TMDL has not yet been completed. Recognizing the importance and unique nature of Lake Chelan, the Subcommittee decided that watershed planning efforts within WRIA 47 should focus on better identifying water quality trends within the lake. The Subcommittee approved a recommendation to develop and implement a long-term monitoring plan (LTMP) for the Lake Chelan. This document summarizes the recommendations and ideas proposed by Subcommittee members for the development of a LTMP and provides an initial framework for the plan. Details regarding sampling locations, analytical methods, and sampling protocols will be provided in a subsequent Quality Assurance Project Plan.

2.0 MONITORING PLAN GOALS AND OBJECTIVES

There is general agreement that the goals of a LTMP should be to address data gaps, identify water quality trends, and provide a proactive monitoring plan for Lake Chelan. The general objectives identified for the LTMP by Subcommittee members are:

- Develop a monitoring design supported by water quality models that can be used to evaluate trends in water quality parameters;
- Evaluate concerns about potential future changes in water clarity and lake eutrophication;
- Develop a monitoring approach for constituents that have completed TMDLs to allow a determination of the effectiveness of post-TMDL remedies (phosphorus, DDT analogs, PCBs);
- Develop a monitoring design for 303(d)-listed constituents in Lake Chelan that have not yet been addressed by completing a TMDL (alpha-BHC, chlordane, dieldrin, dioxins/furans);
- Recommend data quality objectives and analytical methods to ensure greater consistency and comparability of data in the future; and
- Develop a monitoring program that can be used to evaluate best management practices (BMPs) that may be implemented to address water quality concerns.

3.0 WATER QUALITY MODELS

Two models are recommended to evaluate water quality issues within Lake Chelan. CE-QUAL-W2 is well suited to evaluate water clarity/eutrophication issues. The Lake Chelan food web model, which is currently under development, models toxics transfer between sediment, water, and the aquatic food chain. These models are described below.

3.1 CE-QUAL-W2

CE-QUAL-W2 is a two dimensional (longitudinal/vertical) water quality and hydrodynamic model supported by the U.S. Army Corps of Engineers Waterway Experiments Station. The model has been under continuous development and enhancement since 1975. The latest upgrade occurred in January 2008 with the release of Version 3.5 (Cole and Wells, 2008). The model has been widely applied to simulate water quality in lakes and reservoirs. CE-QUAL-W2 allows any combination of constituents to be included or excluded from a simulation. Version 3.5 includes the following water quality state variables in addition to temperature:

- Any number of generic constituents defined along with a decay rate and/or settling velocity and/or Arrhenius temperature rate multiplier to define a conservative tracer, hydraulic residence time, coliform bacteria, or contaminants;
- Any number of phytoplankton, periphyton, macrophyte, and zooplankton groups;
- Nutrients (ammonium, nitrate-nitrite, bioavailable phosphorus);
- Inorganic and organic carbon (labile and refractory and dissolved and particulate species);
- Alkalinity, dissolved oxygen, pH; and
- Organic sediment contributions to nutrients and dissolved oxygen.

CE-QUAL-W2 models basic eutrophication processes such as temperature-nutrient-algae-dissolved oxygen-organic matter and sediment relationships. Application of this model to Lake Chelan would provide a comprehensive framework for understanding relationships among water quality parameters and provide a tool to predict how water quality would be impacted by future changes in nutrient loads or implementation of BMPs.

Application of the model requires that the lake be divided into segments which are arranged in a series along the longitudinal axis of the lake. Three input files (bathymetry file, control file, and meteorological file) must be created for each model application. Data needs for applying the model require information for a water balance (inflows, surface water elevation, and outflows), inflow constituent concentrations, and longitudinal and vertical profiles specifying initial conditions for each cell.

3.2 LAKE CHELAN FOOD WEB MODEL

Lake Chelan has been listed under Section 303(d) of the Clean Water Act for non-attainment of the U.S. Environmental Protection Agency's (EPA's) National Toxic Rule (NTR) criteria for DDE (a degradation product of the insecticide DDT) and PCBs in edible fish tissue. The Washington State Department of Ecology (Ecology) completed a TMDL for DDE and PCBs in 2005. Fish samples collected in the Wapato Basin of Lake Chelan during 2003 showed that fillets from burbot, kokanee, and LAKE trout had total DDT concentrations that exceeded the NTR human health criteria for DDT in fish tissue (32 µg/kg). Fillets for kokanee and lake trout also exceeded the NTR human health criteria for total PCBs in fish tissue (5.3 µg/kg).

Lake Chelan has also been listed for non-attainment of the NTR human health criteria for chlordane, dieldrin, and dioxin/furans in fish tissue based on the analysis of lake trout samples collected near the mouth of Stick Creek during October 2000. TMDLs have not been conducted for these chemicals.

In 2006, the Lake Chelan Water Quality Committee initiated efforts to develop a Lake Chelan food web model (Figure 1). The objective for the initial development of the model was to predict tissue concentrations of DDT and its breakdown products DDE and DDD in the three fish species (burbot, kokanee, and lake trout) that exceed NTR criteria. The modified version of the 1993 Gobas food web bioaccumulation model (Gobas, 1993) was selected to examine the distribution of DDT, DDE, and DDD within Lake Chelan sediments, water, and aquatic biota (Arnot and Gobas, 2004; Gobas and Arnot, 2005). This model has gained general scientific acceptance for predicting chemical residues in aquatic food webs and has been used in a substantial number of scientific and regulatory applications (Burkhard, 1998; Gobas and Arnot, 2005; Gobas et al., 1991; Kelly and Gobas, 2003; Walker and Gobas, 1999). A description of the model theory is provided by Arnot and Gobas (2004). The model can be used to examine the partitioning of sediment DDT to pore water and the overlying water column and to examine the accumulation of DDT in aquatic species from the water and diet. The model simulates two chemical uptake processes: intake via respiratory surfaces and dietary uptake. Four chemical elimination processes are also simulated: elimination via the respiratory surfaces, excretion, chemical metabolism, and growth.

The initial parameterization of the model was completed in March 2006 (Geomatrix, 2006). The final model calibration for DDT analogs, which was originally scheduled for completion prior to June 30, 2009, was discontinued due to funding cuts. This model could be applied to include the other toxics compounds for which TMDLs have not yet been completed (chlordane, dieldrin, and dioxin/furans).

Additional monitoring data that are recommended to reduce model uncertainties include:

- Water column concentrations of dissolved organic carbon (DOC) and particulate organic carbon (POC);
- Tissue concentrations of toxics in key prey species (three-spine stickleback, peamouth chub, mysids); and
- Synoptic data set for toxics concentration in sediment, pore water, and benthic biota.

Once the model is calibrated, it can be used to address important management questions. Some examples include:

- Predict the fraction of tissue contaminants that are derived from water, sediment, and diet.
- How will sediment deposition trends affect tissue concentrations? Total DDT concentration in Wapato Basin sediments increase with depth. Over the depth range of 7 to 0 cm, total DDT concentrations decrease approximately 110 μg/kg with each 1 cm of deposition (i.e., more recent sediments have lower DDT concentrations). Using an estimate of the sediment deposition rate, the model can predict how fish tissue concentrations will change based on future changes in sediment concentrations.
- How will changes in contaminant loads from tributaries and irrigation drains affect fish tissue concentrations?
- The model predicts tissue concentrations increase with fish size. What sizes of burbot, kokanee, or lake trout are predicted to have tissue concentrations below the National Toxics Rule?
- Given predicted changes in fish tissue concentration over time, what monitoring interval should occur to be able to detect statistically significant changes?

4.0 MONITORING PARAMETERS AND FREQUENCY OF SAMPLING

Monitoring programs that are designed around the calibration of models typically have an intensive first phase that is designed to collect sufficient data to calibrate the model. This is followed by less frequent sampling as the model allows a greater understanding of the system and better prediction of the sampling intervals that are necessary to capture measurable changes in parameters. A discussion of the parameters and frequency of sampling is provided for each of the models discussed above.

4.1 CE-QUAL-W2

This model categorizes constituents into four levels, depending on whether they affect phytoplankton/nutrient/dissolved oxygen dynamics and whether they are transported longitudinally or vertically within the lake (Table 1). In order to evaluate water clarity/eutrophication issues in Lake Chelan, Level II and Level IV constituents will need to be monitored. Given the low productivity and steep nearshore bathymetry of most of the lake, Level III constituents are likely not necessary for an understanding of lake eutrophication trends.

Calibration of the model requires monitoring data for the boundary conditions. Boundary conditions frame the grid area that is simulated by the model. Surface boundary conditions and hydraulic parameters are required for model application boundary conditions for inflows; outflows are optional.

Surface boundary conditions include the following:

- **Surface heat exchange** – calculated from latitude, longitude, air temperature, dew point temperature, wind speed and direction, and cloud cover;
- **Solar radiation absorption** – solar radiation is determined from latitude, longitude, and date. Distribution of solar radiation in the water column is controlled by the fraction of radiation absorbed in the surface layer (user specified) and the attenuation rate due to water, inorganic, and organic suspended solids (if modeled);
- **Wind stress** – this boundary condition is determined from wind speed and direction; and
- **Gas exchange** – wind speed is also used for computing gas exchange at the water surface if dissolved oxygen and/or total inorganic carbon are simulated.

Hydraulic boundary conditions include the following:

- **Dispersion/diffusion coefficients** – the model allows selection of default values for horizontal dispersion coefficients for momentum and temperature. The model is relatively insensitive to variation in these values. Vertical diffusion coefficients for momentum and temperature vary in time and space and are computed by the model.
- **Bottom friction** – user can enter different values for the Chezy coefficient or Manning's N for bottom friction for each model cell.

Inflow boundary conditions include the following:

- **Upstream inflows (optional)** – Model provides an option to distribute inflows evenly throughout the inflow segment (farthest up-lake segment – likely would be located in the lower Lucerne Basin) or distribute flows according to density. If this option is used, then a separate file is needed for inflow, temperature, and all constituents that are being modeled (Table 2);

- **Tributary inflows (optional)** – If this option is selected, then the same data requirements as upstream inflow are required for each tributary. If the model was setup to examine the lower Lucerne and Wapato basins, potential tributaries to include would be Twenty-Five Mile Creek, Stink Creek, First Creek, Knapp Coulee Creek, and Purtteman Creek.

- **Distributed tributary inflows (optional)** – these flows represent non-point source inflows that are distributed throughout a segment weighted by the segment surface area. It is unlikely that initial inflows would be specified. However, through the calibration process inflows could be specified to obtain a better fit to collected data. Nutrient input via septic systems or groundwater influx of contaminants could be modeled using this boundary parameter.

Outflow boundary conditions include the following:

- **Downstream outflows (optional)** – for Lake Chelan this would be the water leaving the lake at Chelan Dam. The model allows specification of the depth interval over which water outflow occurs.

- **Lateral withdrawals (optional)** – this option could be used if water loss for human consumption and/or irrigation has a significant impact on the water balance (unlikely).

- **Evaporation (optional)** – this is calculated from air and dew point temperature and wind speed.

As noted above, several of the boundary condition parameters are provided by the model as default values, or are calculated from meteorological data that can be obtained from local or regional reporting stations. The minimum requirement for each boundary cell (upstream inflow or tributary) would be to monitor temperature, total organic carbon, soluble reactive and total phosphorus, nitrate+nitrite, and ammonium (Table 2). Table 2 also shows additional parameters that would substantially improve the predictive capability of the model. Cole and Wells (2008) recommend a weekly sampling frequency that includes capturing storm events. This frequency, while desirable, would not be necessary for an initial calibration of the model. Monthly sampling is recommended for collecting data to calibrate the portion of the lake being modeled (Table 3).

Monitoring data is also needed for each model segment established to simulate water quality conditions in the lake. Each segment would span the width of the lake and a specified longitudinal distance upstream. Typically these segments are setup to capture only one tributary inflow, if that option is being simulated. The minimum amount of monitoring data would collect data from several depths at one location in the middle of the cell. Multiple sites could be sampled if lateral variability is suspected (if this is determined, the model can be setup to evaluate branch segments). Table 3 shows the minimum number of parameters required to simulate the eutrophication features of the model. Additional parameters that would substantially enhance the predictive capability of the model are also shown in Table 3. All of the parameters shown except phytoplankton biomass and type and biological oxygen demand are recommended for initial model calibration.

4.2 Lake Chelan Food Web Model

Section 3.2 identified additional data that would assist in the initial calibration of the food web model. Once the model is calibrated, it is recommended that the parameters shown in Table 4 be monitored at a frequency of once every 3 to 5 years. Fish tissue and mid-lake sediment samples were last collected in Lake Chelan in 2003. The collection and evaluation of data with the Lake Chelan food web model would provide the effectiveness monitoring required for the DDT and PCB TMDL and perhaps meet the requirements for completing a TMDL for chlordane, dieldrin, and dioxins/furans.

5.0 NEXT STEPS

The next steps in completing a long-term monitoring plan for Lake Chelan will include the following:

- Watershed Planning Committee approval of the application of the models recommended in this report (or alternative models);
- Watershed Planning Committee approval of the constituents to be monitored and the sampling frequency and design;
- Completion of a Quality Assurance Plan for the monitoring program; and
- Implementation of the plan once funding is secured.

6.0 REFERENCES

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TABLES

TABLE 1

CONSTITUENT LEVEL CATEGORIES IN CE-QUAL-W2

WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Level	Group Characterization	Constituent
I	No interaction with phytoplankton/nutrient/ DO dynamics	Total dissolved solids
		General constituents
		Inorganic suspended solids
II	Affect phytoplankton/nutrient/DO dynamics	Dissolved inorganic Phosphorus
		Ammonium
		Nitrate-Nitrite
		Dissolved silica
		Particulate biogenic silica
		Total iron
		Labile and refractory DOM
		Labile and refractory POM
		CBOD
		DO
		zooplankton
		phytoplankton
III	Constituents that interact with Level II constituents but are not transported	Periphyton
		Organic sediments
		Macrophytes
IV	Necessary for computing pH and carbonate species; Model state variables	Total inorganic carbon
		Alkalinity

Abbreviations
BOD: biological oxygen demand
CBOD: carbonaceous biological oxygen demand
DO: dissolved oxygen
DOM: dissolved organic matter
POM: particulate organic matter

TABLE 2

GENERAL GUIDELINES FOR SAMPLING BOUNDARY CONDITIONS
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Minimum Parameters	Additional Parameters	Sampling Frequency
Inflow and Outflow Temperature	Conductivity, DO, pH Total Dissolved Solids[1]	Daily or continuous
TOC	DOC, POC, BOD[2]	Weekly, with storm sampling
Soluble Reactive Phosphorus Total Phosphorus	Total Dissolved Phosphorus Total Inorganic Phosphorus Dissolved Inorganic Phosphorus	Weekly, with storm sampling
Nitrate + Nitrite Ammonium	Total Kjeldahl Nitrogen Dissolved Kjeldahl Nitrogen	Weekly, with storm sampling
	TSS[3]	Weekly, with storm sampling
	Chlorophyll a Dissolved silica[4] Alkalinity	Weekly, with storm sampling

Notes
1. Enough samples to correlate to conductivity (important for density effects).
2. Used to characterize decay rates of organic matter.
3. Suspended solids affect phosphorus partitioning, light penetration, and density.
4. May be limiting for diatom growth.

Abbreviations
BOD: biological oxygen demand
DO: dissolved oxygen
DOC: dissolved organic carbon
POC: particulate organic carbon
TOC: total organic carbon
TSS: total suspended solids

TABLE 3

GENERAL GUIDELINES FOR IN-POOL WATER QUALITY SAMPLING

WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Minimum Parameters	Additional Parameters	Sampling Frequency
Temperature[1], DO[1], pH[1] Conductivitry[1]	Total Dissolved Solids[2]	Monthly
Chlorophyll *a*[3]	Phytoplankton biomass and type (e.g., diatoms, green, blue-green)	Monthly
TOC[3]	DOC, POC, BOD	Monthly
Soluble Reactive Phosphorus[3] Total Phosphorus[3]	Total Dissolved Phosphorus Total Inorganic Phosphorus Dissolved Inorganic Phosphorus	Monthly
Nitrate + Nitrite[3] Ammonium[3]	Total Kjeldahl Nitrogen Dissolved Kjeldahl Nitrogen	Monthly
	Secchi depth/light transmission	Monthly
	Total inorganic carbon Alkalinity TSS	Monthly

Notes

1. Preferably biweekly; samples should be taken at 1-meter intervals.
2. Enough samples to correlate with conductivity.
3. Minimum number of samples includes one each in epilimnion, metalimnion, and hypolimnion; preferred sampling would be at 3-meter intervals.

Abbreviations

BOD: biological oxygen demand
DO: dissolved oxygen
DOC: dissolved organic carbon
POC: particulate organic carbon
TOC: total organic carbon
TSS: total suspended solids

TABLE 4

MONITORING RECOMMENDATIONS FOR THE LAKE CHELAN FOOD WEB MODEL

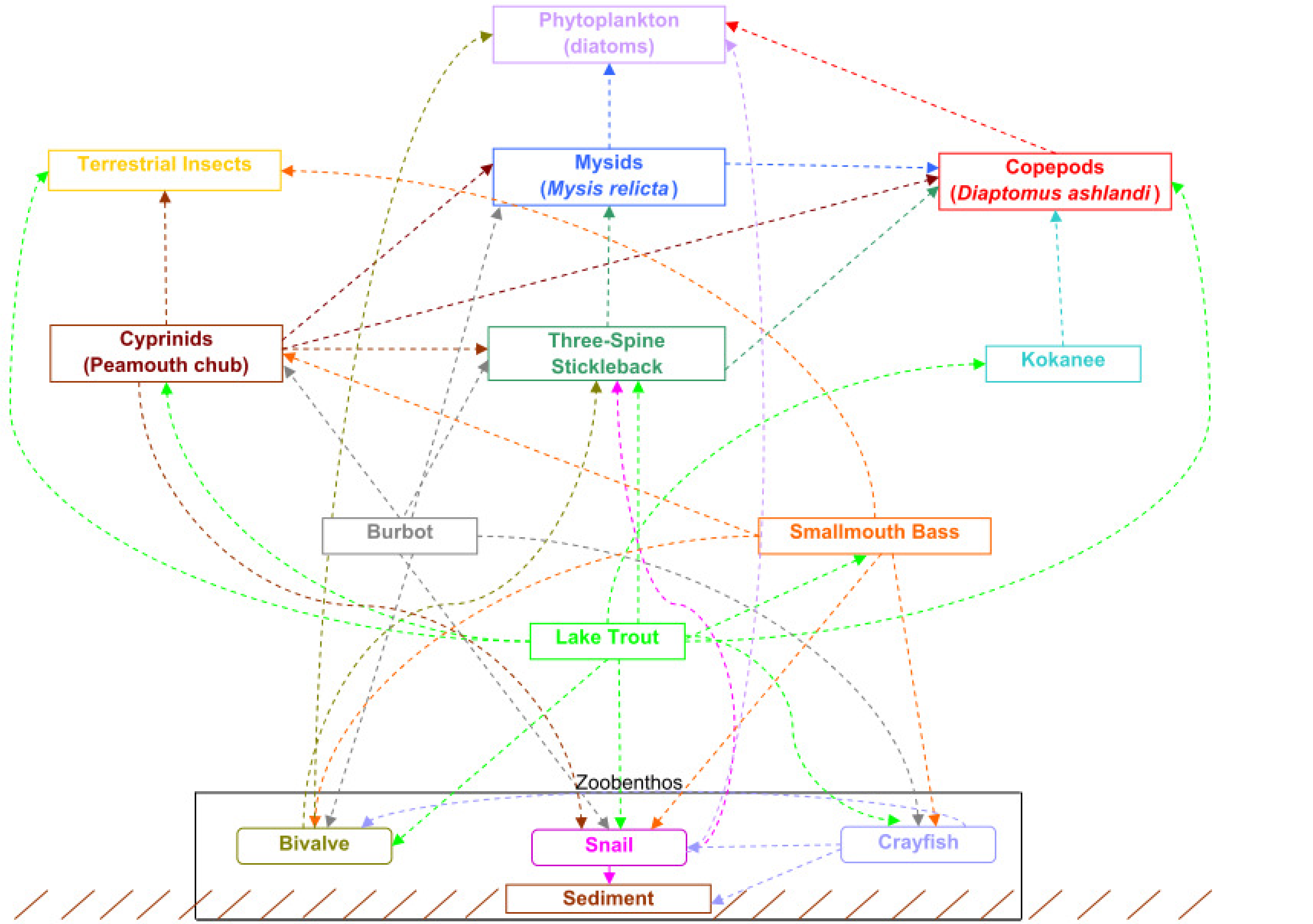
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Parameter	Sample Description	Sampling Frequency
TMDL fish species[1]	Composite fillets without skin	3 to 5 years
Key prey species[2]	Composite whole-body	3 to 5 years
TMDL constituents in sediment[3]	Several samples along mid-lake transect	3 to 5 years
Freely dissolved TMDL constituents[3]	SPMD deployments for approximately 30 days	3 to 5 years

Notes
1. Burbot, kokanee, lake trout.
2. Mysids, three-spine stickleback.
3. Chlordane, dieldrin, dioxins/furans, DDT analogs, polychlorinated biphenyls (PCBs).

Abbreviations
SPMD: semipermeable membrane device
TMDL: total maximum daily load

FIGURES



CONCEPTUAL DIAGRAM SHOWING ORGANISMS INCLUDED IN THE LAKE CHELAN CONTAMINANT FOOD WEB MODEL WRIA 47 Phase II Watershed Planning Chelan County, Washington		
By: sge	Date: 06/22/09	Project No. 13462.002
AMEC Geomatrix		Figure 1

APPENDIX A

Assessment of Water Quality Issues Within WRIA 47

Memo

To:	Paul Cross, RH2 Engineering, Inc.	Project:	13462.002.0
From:	Steve Ellis, Ph.D.	cc.	Mike Kaputa, Chelan County Natural Resource Department
Tel:	(425) 921-4000		
Fax:	(425) 921-4040		
Date:	December 21, 2009		

Subject: Assessment of Water Quality Issues Within WRIA 47, WRIA Phase II Watershed Planning

This memorandum describes the five reporting categories for classifying the water quality status of waters within Washington State, identifies the parameters and waterbodies within Water Resource Inventory Area (WRIA) 47 listed in these categories, and discusses the requirements for developing a pollution control plan that would allow water quality issues to be addressed through the Category 4B process. This information is intended to assist the initiating governments (Chelan County, City of Chelan, and the Lake Chelan Reclamation District) to make decisions regarding the actions that may occur during Phase II water quality planning within WRIA 47.

Water Quality Categories

The U.S. Environmental Protection Agency (EPA) advocates the use of a five-part categorization format for classifying water quality for state reporting requirements under Sections 303(d), 305(b), and 314 of the Clean Water Act (EPA, 2005). State reporting requirements under these regulations are summarized below (EPA, 2005):

- **Section 303(d**) – By April 1 of all even-numbered years, a list of impaired and threatened[1] waters still requiring total maximum daily loads (TMDLs); identification of the impairing pollutant(s); and priority ranking of these waters, including waters targeted for TMDL development within the next 2 years.

- **Section 305(b)** – By April 1 of all even-numbered years, a description of the water quality of all waters of the state.

- **Section 314** – In each Section 305(b) submittal an assessment of status and trends of significant publicly owned lakes including extent of point source and nonpoint source impacts due to toxics, conventional pollutants, and acidification.

[1] EPA recommends that states consider as threatened those waters that are currently attaining water quality standards, but which are expected to not meet standards by the next listing cycle (2 years).

AMEC Geomatrix, Inc.
3500 188th Street SW, Suite 600
Lynnwood, Washington
USA 98037-4763
Tel (425) 921-4000
Fax (425) 921-4040
www.amecgeomatrixinc.com

AMEC Geomatrix

The Washington State Department of Ecology (Ecology) uses the following five category system for classifying water quality with in the state.

- **Category 1** – All designated uses are supported, no use is threatened. Parameters listed under this category for a waterbody are those that have been analyzed and found to meet applicable water quality standards.

- **Category 2** – Available data and/or information indicate that not all beneficial uses are fully supported. Ecology designates waters under Category 2 as "waters of concern." Examples of situations for this listing include: (1) not enough violations of water quality standards have been documented to categorize it as impaired according to Ecology's listing policy (Ecology, 2006a); (2) data showing water quality violations may not have been collected using proper scientific methods[2]; or (3) a waterbody might have pollution levels that are not quite high enough to violate water quality standards (Ecology, 2004a).

- **Category 3** – Insufficient data and/or information are available to make beneficial use support designation. Ecology does not list waterbodies that have not been tested, but if they do not appear in one of the other categories, they are assumed to be under Category 3 (Ecology, 2004a).

- **Category 4** – Available data and/or information indicate that at least one designated use is not being supported or is threatened, but a TMDL is not needed. Three subcategories are used to indicate why a TMDL is not required (Ecology, 2004a):
  - **Category 4A** – A TMDL has been completed and approved by EPA. The actions described in the TMDL to come into compliance with water quality standards are being implemented.
  - **Category 4B** – A TMDL is not required because an approved pollution control plan is in place. Pollution control plans have many of the same features as TMDLs and there must be some legal or financial guarantee that they will be implemented.
  - **Category 4C** – The waterbody is impaired by a non-pollutant that cannot be addressed through a TMDL. Examples of non-pollutants include low water flow, stream channelization, dams, and invasive exotic species.

- **Category 5** – Available credible data[2] indicate that at least one designated use is not being supported or is threatened, and a TMDL is required.

Waterbodies that have Category 5 parameters that are not meeting water quality standards comprise what is called the 303(d) list. New listings are initiated by Ecology's "call for data"; the most recent 60-day period for data submission closed on November 7, 2006. The submitted

[2] The Water Quality Data Act codified in RCW 90.48.570 through 90.48590 requires that Ecology shall use credible data for determining whether any surface water of the state is supporting its designated use or other classification. Data are considered credible only when appropriate quality assurance and quality control procedures were followed and documented in collecting and analyzing water quality samples.

data is assessed in accordance with Ecology Policy 1-11 (Ecology, 2006a, 2006b). The most recent draft 303(d) list was published for public review and comment during February 5 – March 21, 2008 and April 16 – 30, 2008. Following the review of public comments, Ecology submitted an integrated report[3] that included the candidate 303(d) list for EPA approval on June 23, 2008. The 2008 water quality assessment and updated 303(d) list was approved by EPA on January 29, 2009.

Ecology Policy 1-11 (Ecology, 2006a) describes the minimum amount of data that is required for a Category 5 listing and over what historical period the data are considered representative of current conditions. The Policy indicates that data submitted by the public which are less than 5-years old and meet the requirements outlined in the policy will be consolidated and assessed with other data of the same waterbody segment and parameter. Data older than 5 years will only be considered by Ecology on a case-specific basis. This 5-year requirement differs from the Category 5 assessment methodology described in Section 6 of the Policy, which states that *"newly submitted data will be added to previously assessed data that are less than 10-years old."*

The Category 5 determination requirements vary for different water quality parameters. For toxic pollutants, a waterbody segment will be placed in Category 5 due to a toxic pollutant in the water column when two or more samples within a 3-year period exceed the applicable criteria. The segment will also be placed in Category 5 if either the mean of three single-fish samples for a given pollutant or one composite sample made up of at least five fish exceeds the applicable criteria (Ecology, 2006a).

Water Quality Listings within WRIA 47

Table 1 lists the waterbodies and parameters listed under Categories 2 through 5 in WRIA 47 based on the latest approved 303(d) list which was approved by EPA on January 29, 2009.

Several waterbodies have Category 5 listings based on measurements of contaminant concentrations in fish tissue or water:

- In Lake Chelan the listed constituents are organochlorine pesticides (chlordane, dieldrin, alpha-BHC) and dioxins.

- In the Columbia River the listed constituents are organochlorine pesticides (4,4'-DDD, 4,4'-DDE), total PCB, and temperature.

[3] EPA (2005) recommends that States submit an integrated report that satisfies the reporting requirements of sections 303(d), 305(b), and 314.

- Category 5 listings for the Manson Lakes area east of the Lake Chelan Wapato/lower Lucerne basins include dissolved oxygen (Joe Creek, Stink Creek, Wapato Lake outflow), and total phosphorus (Dry Lake and Roses Lake).

- Category 5 listings for creeks discharging to the upper Lucerne Basin in Lake Chelan include lead (Copper Creek, Holden Creek, and Railroad Creek) and copper, mercury, and silver (Railroad Creek).

Approved TMDLs completed for total phosphorus in 1993, and DDT compounds and PCBs in 2006 have resulted in these contaminants being classified as Category 4A in the 2008 303(d) list. TMDL effectiveness monitoring for total phosphorus in Lake Chelan was conducted in 2007 (Sargeant, 2007). The water quality improvement plan for DDT compounds and PCBs in Lake Chelan and the Chelan River was submitted for EPA approval on August 5, 2008.

Several waterbodies (Lake Chelan, Chelan River, Columbia River, Dry First Creek, Mitchell Creek, and Wapato Lake) have parameters listed under Category 2 (waters of concern). The listing basis for these parameters is based on limited data collected five or more years ago; therefore, monitoring is needed to confirm the Category 2 listings for these waterbodies.

The state reporting requirements for the Integrated report[3] that is submitted to EPA requires that Ecology submit a schedule and prioritization for the establishment of TMDLs for waters with a Category 5 listing. Ecology's TMDL prioritization and scheduling process is a 5-year process consisting of the following steps:

- Year 1: Scoping;

- Years 2 and 3: Data collection and analysis;

- Year 4: Development of a plan of action; and

- Year 5: Implementation.

The 2008 water quality assessment approved by EPA indicates that the TMDL process for Category 5 waters in WRIA 47 will occur from 2011 to 2116 (Ecology, 2009).

Category 4B Requirements

EPA guidance recognizes that alternative pollution control requirements may substitute for the need to complete a TMDL (EPA, 2005). Segments within waterbodies are not required to be included on the Section 303(d) list if: "*technology-based effluent limitations required by the [Clean Water] Act, more stringent effluent limitations required by state, local, or Federal authority, or other pollution control requirements (e.g., best management practices) required by* *local, state, Federal authority are stringent enough to implement applicable water quality standards within a reasonable period of time."*

Ecology (2004b) provides the following criteria that must be met for a Category 5 constituent to be proposed for listing under Category 4:

- Have enforceable pollution controls or actions stringent enough to attain the water quality standard of standards;
- Be problem-specific and waterbody-specific;
- Have reasonable time limits established for correcting the specific problem, including for interim targets when appropriate;
- Have a monitoring component;
- Have adaptive management built into the plan to allow for course corrections if necessary;
- Be feasible, with enforceable legal or financial guarantees that implementation will occur; and
- Be actively and successfully implemented and show progress on water quality improvements in accordance with the plan.

Ecology (2004b) indicates that the timeframe for correcting the impairment will be considered reasonable if it is as fast as practical given full cooperation of all parties involved and if it is similar to the timeframe that would be developed under a TMDL. Monitoring must be scheduled to verify that the water quality standards or interim targets are attained as expected. Modeling may be required to show that attainment of water quality standards is likely. Documentation must be provided to clearly explain and support how the pollution control plan meets the criteria for each specific pollutant and waterbody.

Ecology (2004b) provides five examples of successful pollution control plans that justified listings under Category 4B. The example most relevant to watershed planning efforts in WRIA 47 is the Category 4B listing for temperature in WRIA 46. The approved Entiat WRIA 46 Management Plan developed as part of watershed planning efforts in this watershed was reviewed by Ecology and was determined to meet the criteria for listing under Category 4B.

References:

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APPENDIX TABLE

TABLE 1

WATER QUALITY LISTINGS WITHIN WRIA 47

Chelan County, Washington

Category	Waterbody	Parameter	Medium	Listing Basis
5[1]	Lake Chelan	Chlordane	Tissue	EPA National Lake Fish Tissue Study shows an excursion beyond the National Toxics Rule criterion in lake trout composite samples collected on 10/09/2000 at one location (off Stink Creek).
		Dieldrin	Tissue	EPA National Lake Fish Tissue Study shows an excursion beyond the National Toxics Rule criterion in lake trout composite samples collected on 10/09/2000 at one location (off Stink Creek).
		Dioxin	Tissue	EPA National Lake Fish Tissue Study shows an excursion beyond the National Toxics Rule criterion in lake trout composite samples collected on 10/09/2000 at one location (off Stink Creek).
		Alpha-BHC	Tissue	Hopkins et al. (1985) show excursions beyond the National Toxic Rule criterion in composite samples of edible tissue from bridgelip sucker and northern squawfish; samples were collected in 1984.
5[1]	Columbia River	Temperature	Water	Washington Department of Fish and Wildlife data (submitted September 1995) show numerous excursions beyond the criterion at the inflow to Wells Hatchery.
		4,4'-DDD	Tissue	Fillet samples of northern pikeminnow and mountain whitefish collected from Lake Entiat in 2004 exceeded the National Toxics Rule criterion.
		4,4'-DDE	Tissue	Fillet samples of northern pikeminnow, peamouth, and mountain whitefish collected from Lake Entiat in 2004 exceeded the National Toxics Rule criterion.
		Total PCB	Tissue	Fillet samples of northern pikeminnow, peamouth, and mountain whitefish collected from Lake Entiat in 2004 exceeded the National Toxics Rule criterion.
5[1]	Copper Creek	Lead	Water	Samples collected on 5/23/97 and 7/11/97 exceeded chronic water quality criterion.
5[1]	Dry Lake	Total Phosphorus	Water	In 2002, the summer epilimnetic mean concentration of total phosphorus exceeded the action value for this ecoregion (35 µg/L).
5[1]	Holden Creek	Lead	Water	Samples collected on 5/19/97, 7/10/97, 9/15/97, and 10/4/97 exceeded chronic water quality criterion.
5[1]	Joe Creek	Dissolved Oxygen	Water	In 2003, 4 of 11 samples (36.4%) showed an excursion of the criterion.

TABLE 1

WATER QUALITY LISTINGS WITHIN WRIA 47
Chelan County, Washington

Category	Waterbody	Parameter	Medium	Listing Basis
5[1]	Railroad Creek	Copper	Water	Samples collected during April - June 1997, May 1998, May 2001, and June 2002 exceeded chronic water quality criterion.
		Lead	Water	Samples collected during May - July and September 1997 exceeded chronic water quality criterion.
		Mercury	Water	Samples collected on 5/19/97, 5/22/97, and 7/10/97 exceeded chronic water quality criterion.
		Silver	Water	Two samples collected on 5/20/97 exceeded chronic water quality criterion.
5[1]	Roses Lake	Total Phosphorus	Water	In 2002 the summer epilimnetic mean concentration of total phosphorus samples exceeded the action value for this ecoregion (35 µg/L). Data from 2005 shows a value below the action value (34.5 µg/L).
5[1]	Stink Creek	Dissolved Oxygen	Water	In 2002, 2003, and 2004 greater than 10 percent of the samples collected exceeded the water quality criterion.
5[1]	Wapato Lake	Dissolved Oxygen	Water	In 2003, 5 of 11 samples collected from the Wapato Lake outflow exceeded the water quality criterion.
4A[2]	Lake Chelan	4,4'-DDD	Tissue	Composite samples of burbot, kokanee, and lake trout and individual samples of rainbow trout and lake trout exceeded the National Toxics Criterion.
		4,4'-DDE	Tissue	Composite samples of burbot, kokanee, and lake trout and individual samples of rainbow trout and lake trout exceeded the National Toxics Criterion.
		4,4'-DDT	Tissue	Composite samples of burbot, kokanee, and lake trout and individual samples of rainbow trout and lake trout exceeded the National Toxics Criterion.
		Total PCB	Tissue	TMDL approved Sept. 11, 2006.
		Total phosphorus	Water	TMDL approved Jan. 26, 1993.
4A[2]	Roses Lake	4,4'-DDE	Tissue	Fillet samples of largemouth bass collected in 2003 exceeded the National Toxics Rule criterion.
4C[3]	Lake Chelan	Invasive exotic species		Eurasian water-milfoil.
4C[3]	Domke Lake	Invasive exotic species		Eurasian water-milfoil.

TABLE 1

WATER QUALITY LISTINGS WITHIN WRIA 47

Chelan County, Washington

Category	Waterbody	Parameter	Medium	Listing Basis
4C[3]	Roses Lake	Invasive exotic species		Eurasian water-milfoil.
4C[3]	Wapato Lake	Invasive exotic species		Eurasian water-milfoil.
2[4]	Lake Chelan	pH	Water	Hallock (2001) Dept. of Ecology Ambient Monitoring Station 47A070 (Chelan R @ Chelan) shows 1 excursion beyond the criterion out of 12 samples collected between 1993 - 2001.
		Temperature	Water	Anchor Environmental, 2000, shows the 7-day mean of maximum daily values was exceeded throughout July and August 2002.
2[4]	Chelan River	Temperature	Water	Anchor Environmental, 2000, shows the 7-day mean of maximum daily values was exceeded throughout July and August 2002.
2[4]	Columbia River	Temperature	Water	Hallock (2001) Dept. of Ecology Ambient Monitoring Station 47B070 (Columbia R @ Chelan Station) shows 1 excursion beyond the criterion out of 9 samples collected between 1993 - 2001.
		Dioxin	Tissue	Fillet samples of mountain whitefish collected in 2004 exceeded the National Toxics Rule criterion.
2[4]	First Creek	Dissolved oxygen	Water	Patmont et al. (1989), two excursions beyond the criterion, at the mouth, between 12/86 and 11/87.
2[4]	Joe Creek	pH	Water	In 2003, 1 of 11 samples (9.1%) showed an excursion of the criterion (1 high ph excursion).
2[4]	Mitchell Creek	pH	Water	Patmont et al. (1989), two excursions beyond the criterion out of 13 samples (15%), at the mouth, on 7/28/87 and 6/16/87.
2[4]	Wapato Lake	Dieldrin	Tissue	Johnson (1997) shows one estimated excursion beyond the criterion in a composite of 8 rainbow trout fillets collected in 1996.

Note(s)

1. Data exists showing water quality standards have been violated and there is no TMDL or pollution control plan. TMDL is required.
2. An approved TMDL exists and is being implemented.
3. Impaired by a non-pollutant that cannot be addressed through a TMDL.
4. Waters of concern. Some evidence of a water quality problem, but not enough to require production of a TMDL at this time.

APPENDIX B

Review and Summary of Existing Water Quality Studies Within WRIA 47

Memo

To:	Paul Cross, RH2 Engineering, Inc.	Project:	13462.002.0
From:	Steve Ellis, Ph.D.	cc.	Mike Kaputa, Chelan County Natural Resource Department
Tel:	(425) 921-4000		
Fax:	(425) 921-4040		
Date:	December 21, 2009		

Subject: Review and Summary of Existing Water Quality Studies Within WRIA 47, WRIA Phase II Watershed Planning

This memorandum provides an overview and summary of water quality studies that have been conducted within Water Resource Inventory Area (WRIA) 47. In addition, information is presented to evaluate our ability to detect trends using the historical data. This information is intended to assist the initiating governments (Chelan County, City of Chelan, and the Lake Chelan Reclamation District) that are leading the Phase II watershed planning efforts in WRIA 47 to make decisions regarding the need for water quality planning and the development of a long-term monitoring program within the watershed.

Existing Data

Publicly available reports, memoranda, and databases that present water quality data or discuss water quality conditions within WRIA 47 over the last 40 years were reviewed. An annotated bibliography of the sources of information identified is provided in Attachment A. Attachment A also identifies briefing memoranda and quality assurance project plans (QAPPs) that contain compilations of historical data.

Table 1 identifies the water quality parameters that have been analyzed within WRIA 47 by 16 studies conducted from 1972 to 2007. The table shows that while a large list of conventional water quality parameters and toxics have been measured, there are relatively few parameters that have been consistently measured by the various studies. Common parameters that were monitored in at least half of the studies, in order of decreasing frequency, include temperature, conductivity, pH, nitrate+nitrite, total phosphorus, total suspended solids (TSS), dissolved oxygen (DO), and turbidity.

Bacteria were commonly analyzed in studies conducted prior to 1995, but have not been analyzed in more recent studies. Analysis of metals was conducted as part of a comprehensive water quality study of Lake Chelan conducted during 1986-1987. However, with the exception of monitoring studies conducted in the vicinity of Holden Mine, no recent data have been collected. A comprehensive examination of a large suite of organic compounds has only occurred at one site within WRIA 47. Stink Creek water samples were analyzed for 161

AMEC Geomatrix, Inc.
3500 188th Street SW, Suite 600
Lynnwood, Washington
USA 98037-4763
Tel (425) 921-4000
Fax (425) 921-4040
www.amecgeomatrixinc.com

pesticide and pesticide degradation products as part of a statewide pesticide monitoring program. Table 1 lists the 33 pesticides detected within Washington State.

Water quality sampling within WRIA 47 has occurred mainly within the Wapato Basin of Lake Chelan, Manson Lakes, and in the vicinity of Holden Mine. The sampling locations for surface water data contained in the Washington State Department of Ecology's (Ecology) EIM database for WRIA 47 and studies conducted by AMEC Geomatrix, Inc., is shown on Figure 1.

Water quality is often interpreted more broadly than just the analysis of water and can include information on sediment quality and contaminant concentrations in biota. A list of studies that have information on these other types of data in WRIA 47 is included in Attachment B.

Water Quality Trends

Temporal trends in water quality are ideally determined through the implementation of a statistically-based monitoring program which collects data at designated stations using consistent methods and analytical techniques. Most of the studies that have collected data within WRIA 47 (see Table 1 and Figure 1) were conducted to meet study-specific objectives (see Attachment A) that did not include evaluation of long-term trends in water quality.

Monitoring efforts that were designed by Ecology to evaluate trends include the following:

- Total Maximum Daily Load (TMDL) effectiveness monitoring for phosphate; and
- Ecology water quality monitoring at Station A7A070 near the Lake Chelan outlet.

Phosphorus was identified as the limiting nutrient for aquatic plant growth in Lake Chelan during a comprehensive lake-wide study sponsored by Ecology in 1986-1987 (Patmont et al., 1989). Ecology completed a TMDL for total phosphorus (TP) in 1991 that established a management goal of maintaining the ultra-oligotrophic condition of the Lake Chelan (Pelletier, 1991). This goal was to be met by ensuring that TP loads for various land uses to the lake do not result in a mean epilimnetic (i.e., the upper portion of the water column) TP concentration exceeding 4.5 µg/L.

In 1995 and 1996, the mean epilimnetic TP concentration was measured in the Wapato Basin of Lake Chelan (Congdon, 1996; Sargeant, 1997). In 1995, the mean TP concentration was 2.2 µg/L; in 1996, the mean TP concentration was 2.6 µg/L. Both of these values are statistically less than the TP concentration measured in 1987 (3.5 µg/L). The 1996 TP concentration is also statistically greater than the 1995 TP concentration. All three studies (1987, 1995, and 1996) used different analytical laboratories, different analytical methods, and different sampling personnel. Since we are unable to assess how these study differences may affect the comparability of the data sets, attributing the changes to a "trend" has a large amount of uncertainty. However, the three studies do provide confirmation that TP concentrations in the Wapato Basin are below the TP management goal of 4.5 µg/L.

In 2007, Ecology collected samples to calculate the mean epilimnetic TP concentration in the Wapato Basin (Sargeant, 2007). Sampling stations and collection methods were identical to Ecology's 1996 study. The QAPP did not identify the analytical method that would be used to analyze TP; however, it recommended that methods that could reach lower detection limits than were achieved in 1996 be considered (Sargeant, 2007). The data collected in 2007 has not yet been published, and it is unknown whether any quality assurance procedures were implemented to address any changes in analytical methods. However, the 2007 data, along with the historical data, should help assess TP concentration trends in the Wapato Basin.

Another data set that can be used to assess TP trends in Lake Chelan is monitoring data collected by Ecology at Station 47A070, located near the lake outlet close to Chelan Dam. Water grab samples collected monthly or bi-monthly have been analyzed for TP from 1971 to 1994. The data for each month of the year over this time period is shown on Figures 2 to 7. No statistically significant change in TP concentration occurred at this monitoring location over the 23-year period. However, it should be noted that the high detection limit (10 µg/L) and large number of non-detects in this data set make trends difficult to assess.

References:

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Patmont, C.R., Pelletier, G.J., Welch, E.B., and Ebbesmeyer, C.C., 1989, Lake Chelan Water Quality Assessment: Prepared by Harper Owes, Inc., for Washington State Department of Ecology, Olympia.

Pelletier, G., 1991, Lake Chelan TMDL for Total P: Washington State Department of Ecology, Publication No. 91-e50, Olympia.

Sargeant, D., 1997, Water Quality in the Wapato Basin of Lake Chelan, Summer 1996: Washington State Department of Ecology, Publication No. 97-323, Olympia.

Sargeant, D., 2007, Quality Assurance Project Plan – Lake Chelan Wapato Basin Total Phosphorous TMDL Effectiveness Monitoring, 2007: Washington State Department of Ecology, Publication No. 07-03-109, Olympia.

APPENDIX TABLE

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**12**	**13**	**14**	**15**	**17**	**22**
Water Quality Parameter	**Units**																	
Conventionals																		
Alkalinity	mg CaCO3/L	●					●							●		●		
Ammonia	µg N/L	●			●	●	●		●	●								
Bicarbonate	µg/L						●											
Biological Oxygen Demand	mg/L		●															
Chemical Oxygen Demand	mg/L	●	●		●													
Chloride	mg/L						●											
Chlorophyll a	µg/L	●					●					●	●		●	●		
Cyanide	mg/L													●				
Dissolved Oxygen	mg/L			●			●	●	●	●		●	●		●	●		
Dissolved Oxygen Saturation	%						●						●					
Fluorine	µg/L						●											
Light Extinction Coefficient	1/meter						●											
Nitrogen - Nitrite+Nitrate N	µg N/L	●		●	●	●	●		●	●	●	●	●	●	●	●		
Nitrogen - Total N	µg N/L	●			●		●			●					●			
Nitrogen - Total Persulfate N	ng/L											●	●					
Nitrogen - Total Soluble N	µg N/L						●											
pH		●	●	●	●		●	●	●	●	●	●	●	●	●	●		
Phaeophytin	µg/L						●					●	●					
Phosphorus - Orthophosphate	mg/L				●				●							●		
Phosphorus - Soluble Reactive P	µg P/L						●			●								
Phosphorus -Total P	µg P/L	●		●	●	●	●		●	●		●	●	●	●	●		
Phosphorus - Total Soluble P	µg P/L						●											
Secchi Disk Depth	meters			●			●	●				●	●					
Specific Conductance	µmho/cm	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
Sulfate	mg/L													●				
Temperature	°C		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●
Total Chlorine Residual	mg/L				●													

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		1	2	3	4	5	6	7	8	9	10	24	12	13	14	15	17	22
Water Quality Parameter	**Units**																	
Conventionals (continued)																		
Total Dissolved Gas	%														●			
Total Hardness	mg/L													●				
Total Nonvolatile Suspended Solids	mg/L		●															
Total Organic Carbon	mg/L										●						●	
Total Solids	mg/L		●															
Total Settleable Solids	mg/L		●															
Total Suspended Solids	mg/L		●		●		●		●	●	●			●	●	●	●	
Total Nonvolatile Suspended Solids	mg/L		●															
Transparency															●			
Turbidity	NTU		●		●		●		●	●				●		●	●	
Bacteria																		
Fecal Streptococci	#/100 mL						●											
Fecal Coliform	#/100 mL		●		●	●	●		●	●		●						
Total Coliform	#/100 mL			●			●											
Metals																		
Aluminum	µg/L						●							●				
Arsenic	µg/L						●							●				
Cadmium	µg/L													●				
Calcium	µg/L						●											
Copper	µg/L													●				
Iron	mg/L						●							●				
Lead	µg/L													●				
Managanese	µg/L													●				
Mercury	µg/L													●				
Nickel	µg/L													●				
Silver	µg/L													●				
Zinc	µg/L													●				

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**12**	**13**	**14**	**15**	**17**	**22**
Water Quality Parameter	**Units**																	
Herbicides																		
2,4-D	µg/L										○							
Atrazine	µg/L										○							
Bromacil	µg/L										○							
Bromoxynil	µg/L										●							
Dacthal	µg/L										○							
Dichlorobenil	µg/L										●							
Dichlofop-methyl	µg/L										○							
MCPA	µg/L										○							
MCPP	µg/L										○							
Norflurzaon	µg/L										●							
Norflurazon Desmethyl	µg/L										●							
Simazine	µg/L										●							
Trillate	µg/L										○							
Insecticides																		
Carbaryl	µg/L										○							
Chlorpyrifos	µg/L										●							
4,4'DDD	ng/L															●	●	●
4,4'DDE	ng/L										○					●	●	●
4,4'DDT	ng/L										●					●	●	●
Total DDT	ng/L										●					●	●	●
Diazinon	µg/L										●							
Diuron	µg/L																	
Hexazinone	µg/L																	
3-hydroxycarbofuran	µg/L										●							
Malathion	µg/L										○							
Ozinphos-methyl (Guthion)	µg/L										●							
Terbacil	µg/L																	

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**12**	**13**	**14**	**15**	**17**	**22**
Water Quality Parameter	**Units**																	
Other Organics																		
Bromodichloromethane	µg/L						●											
Chlorodibromomethane	µg/L						●											
Pentachlorophenol	µg/L										●							
PCB Aroclors	µg/L																●	
PCB Congeners	µg/L																	
Tribromomethane	µg/L						●											
Trichloromethane	µg/L						●											

Note(s)

1. See Attachment A for Source references.

● Analyzed Parameter

O Analyzed parameter but not detected

APPENDIX FIGURES

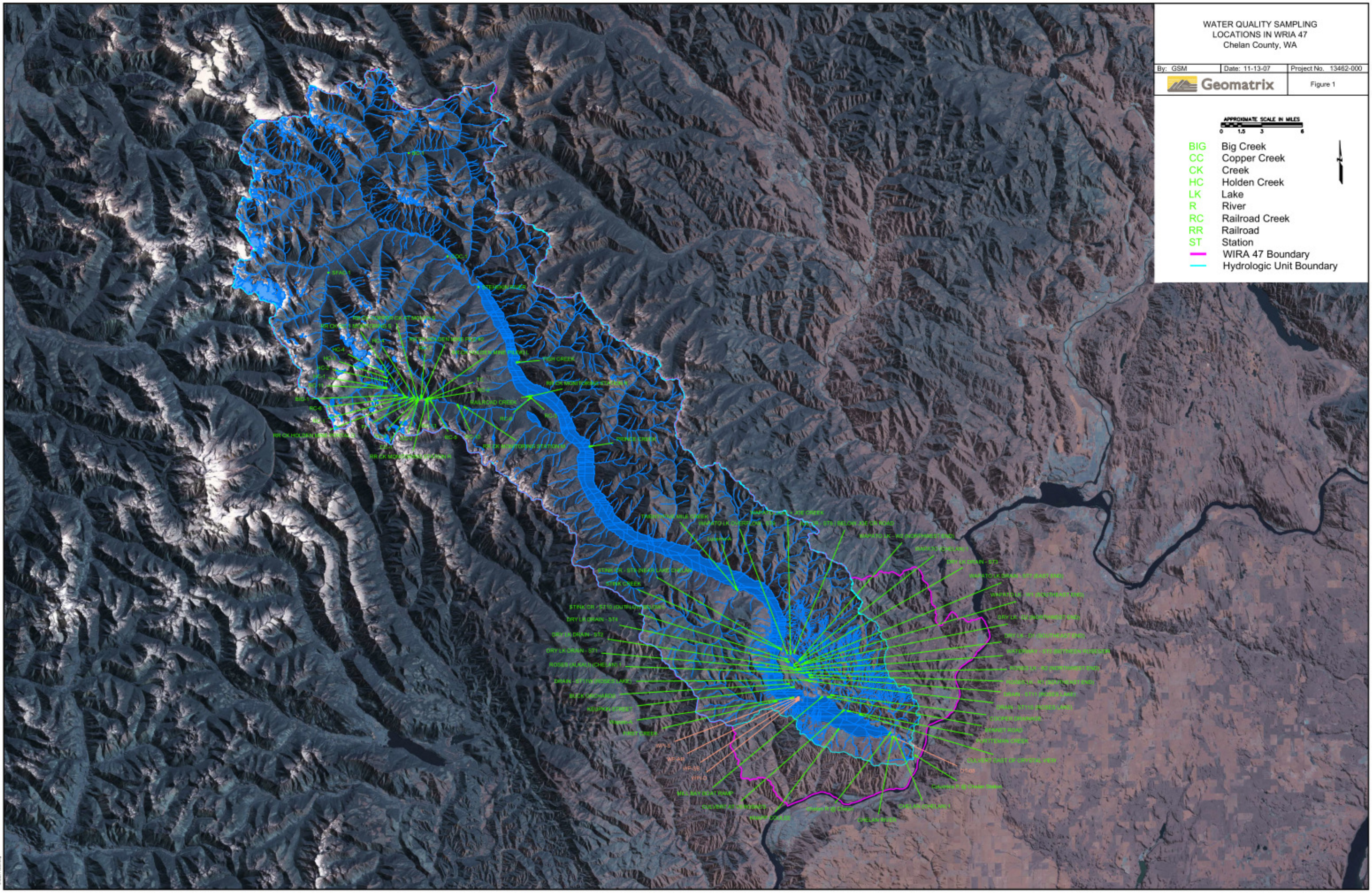
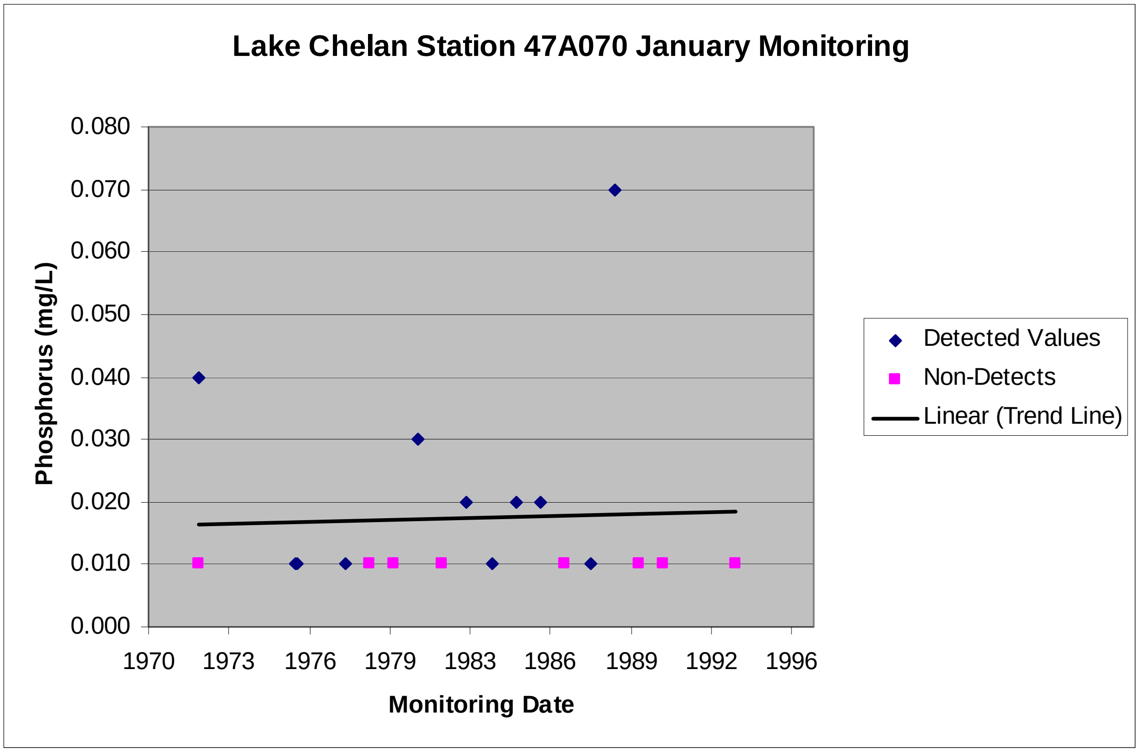
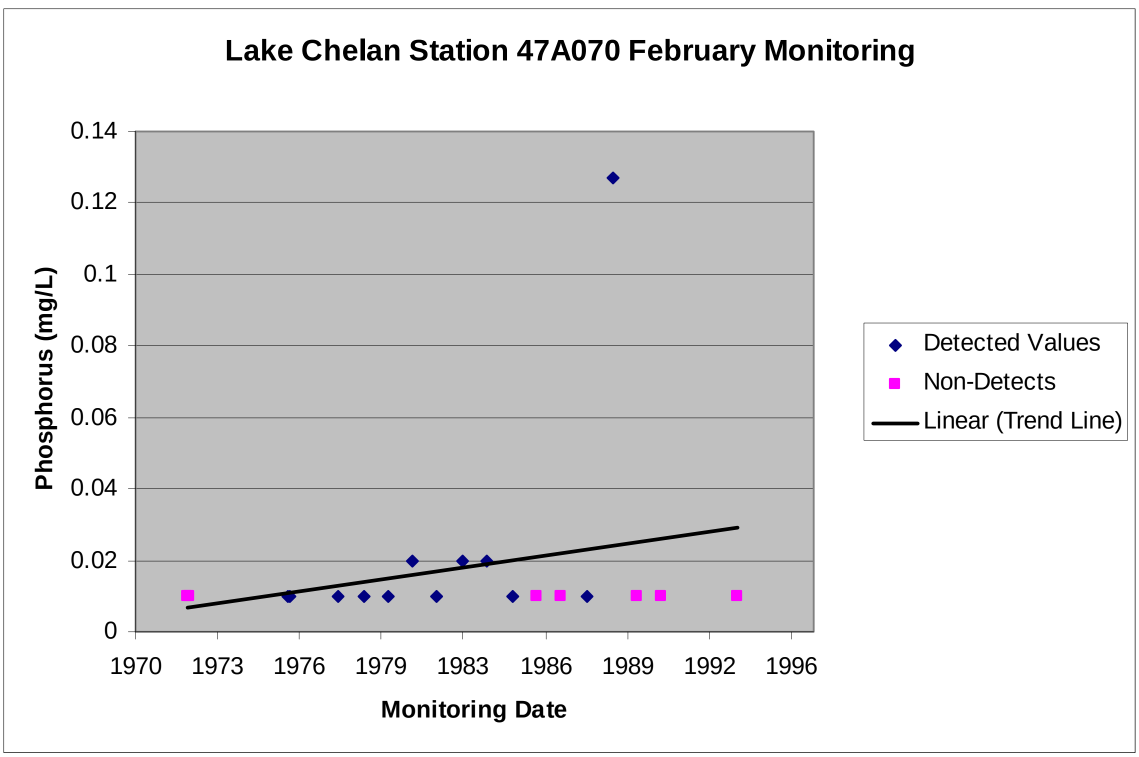


Image Courtesy of NASA Jet Propulsion Laboratory

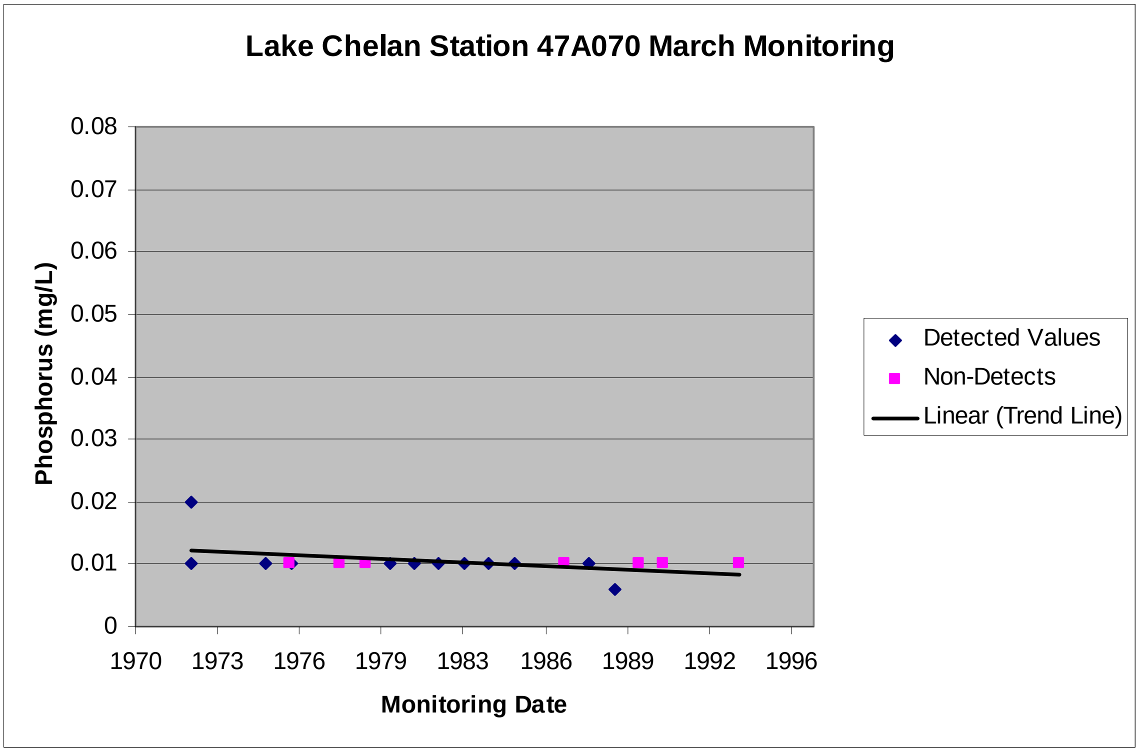


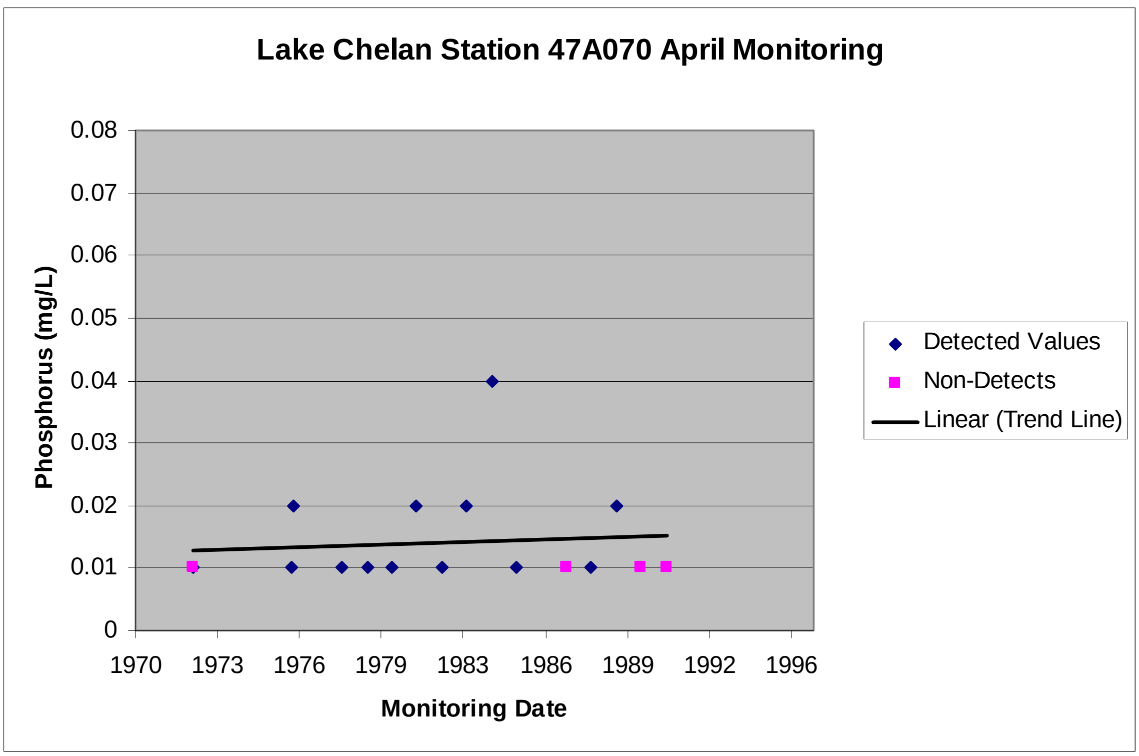


Abbreviation(s)
mg/L = milligrams per liter

PHOSPHORUS MONITORING
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

By: sge	Date: 12/21/09	Project No. 13462.002
AMEC Geomatrix		Figure 2

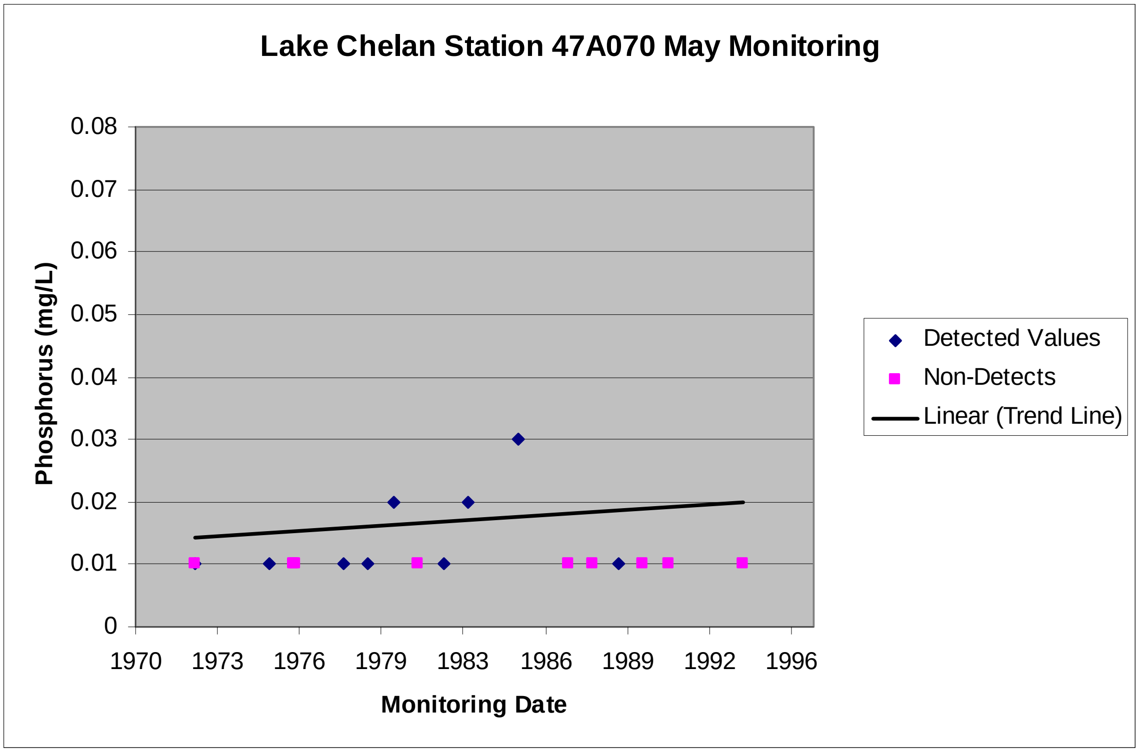


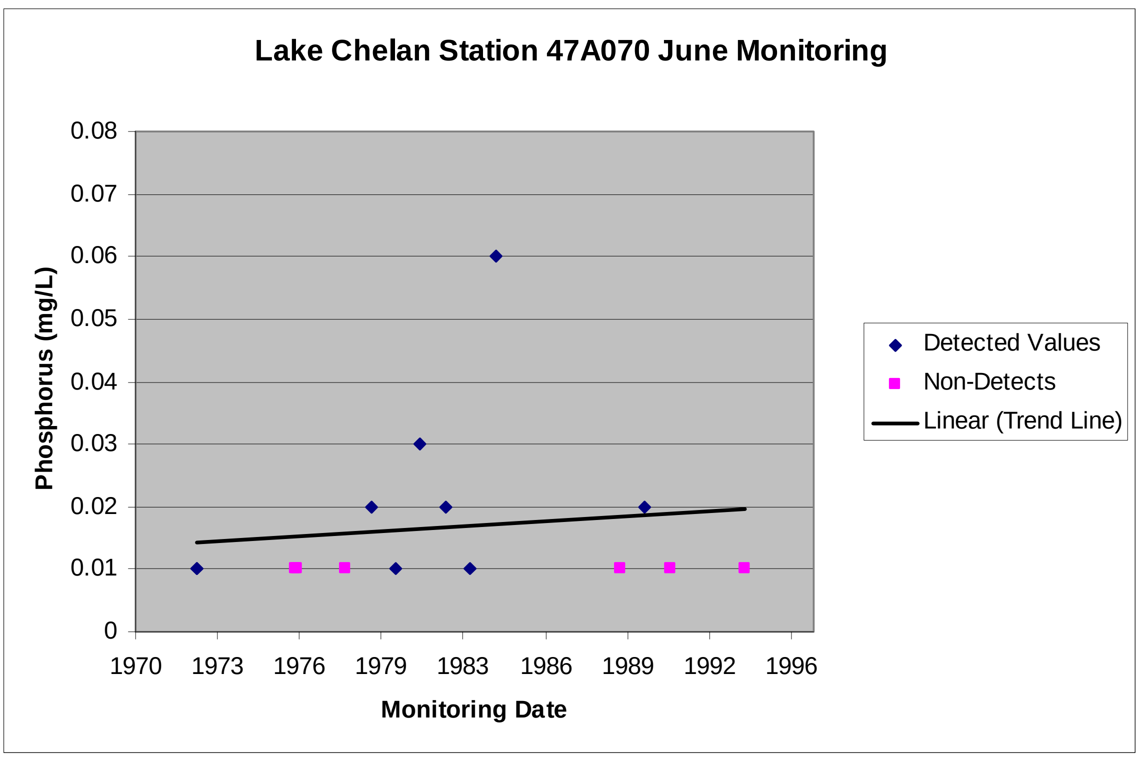


PHOSPHOROUS MONITORING
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

Abbreviation(s)
mg/L = milligrams per liter

By: sge	Date: 12/21/09	Project No. 13462.002
AMEC Geomatrix		Figure 3





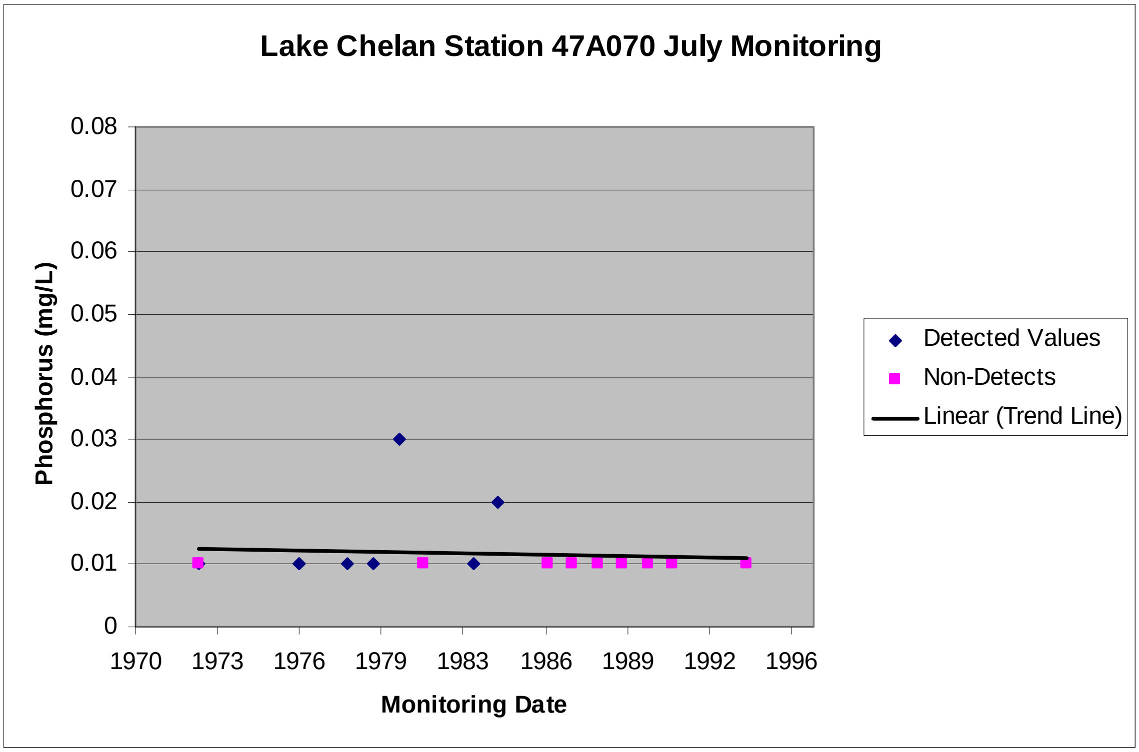
Abbreviation(s)
mg/L = milligrams per liter

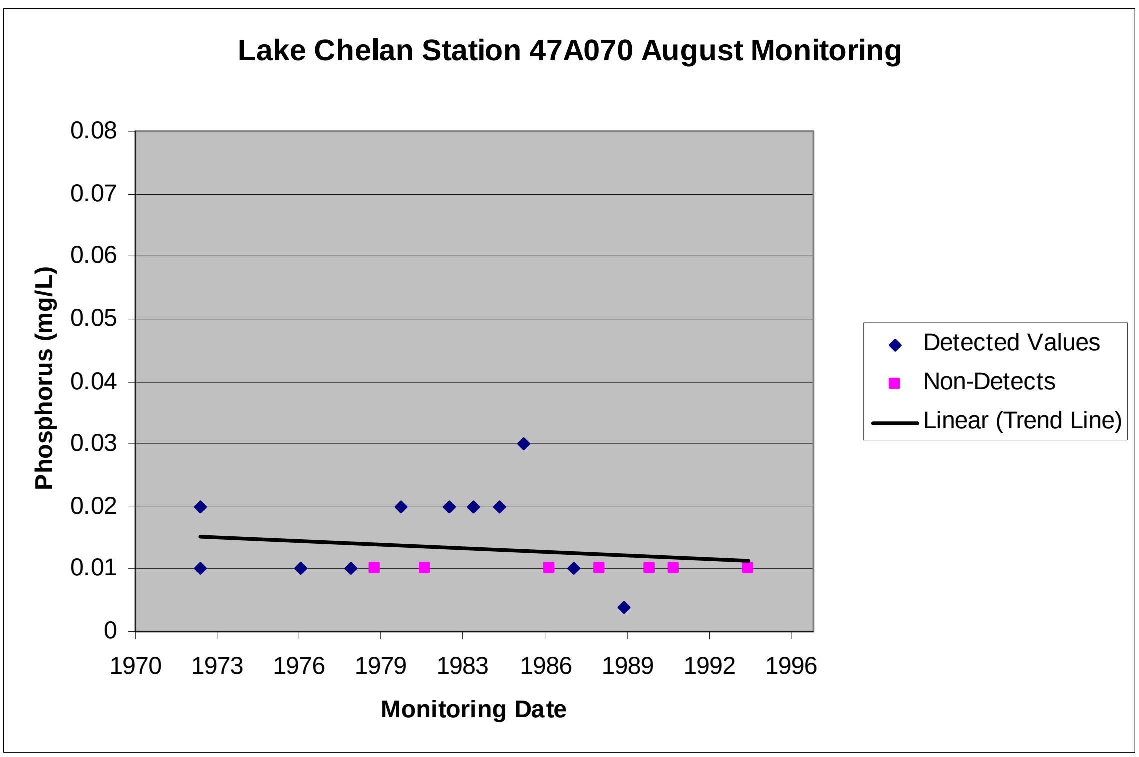
PHOSPHORUS MONITORING
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

By: sge	Date: 12/21/09	Project No. 13462.002

AMEC Geomatrix

Figure 4

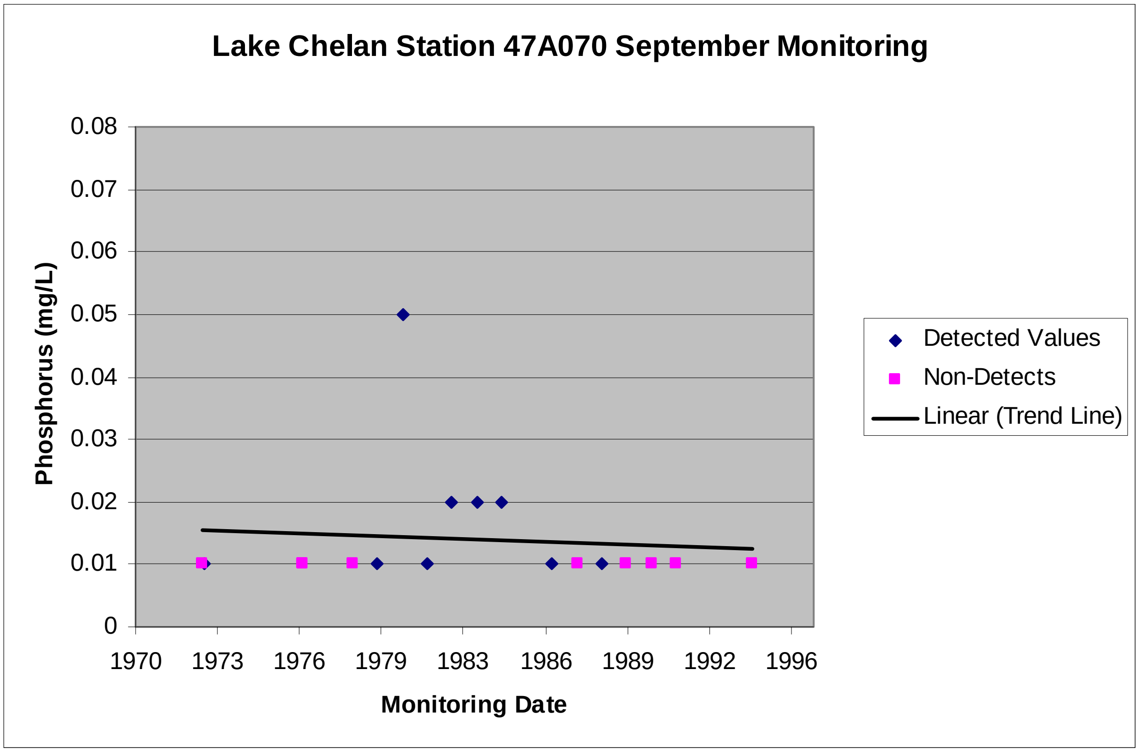


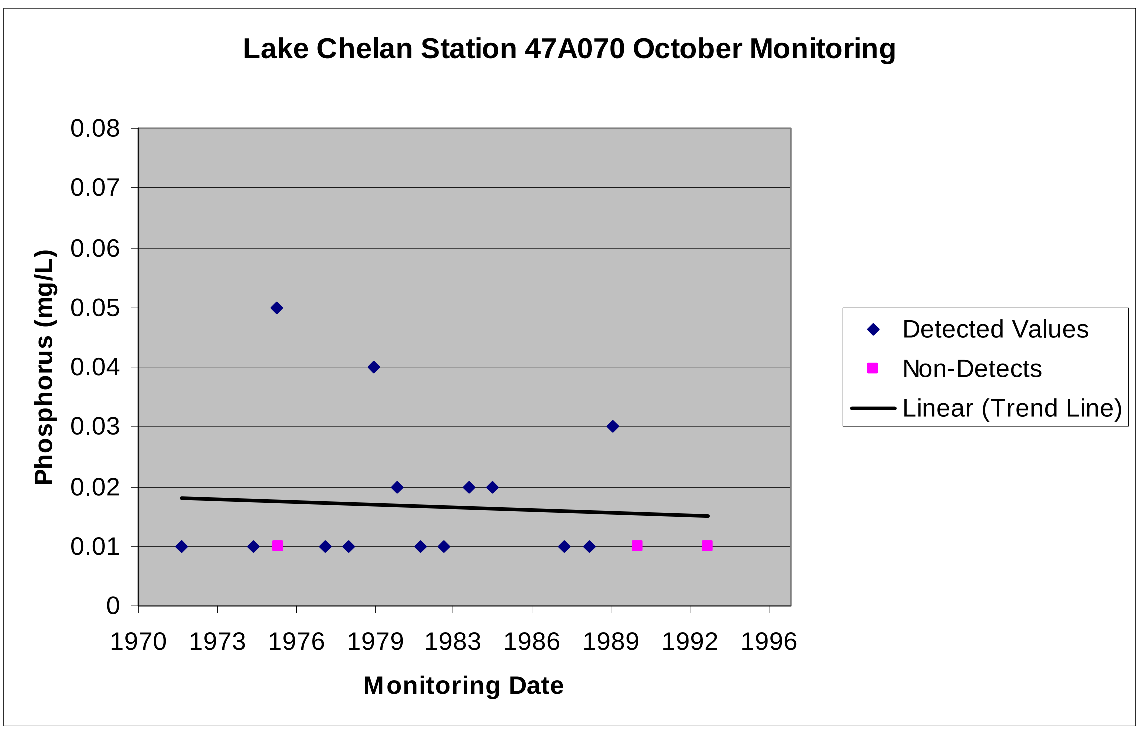


Abbreviation(s)
mg/L = milligrams per liter

PHOSPHORUS MONITORING
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

By: sge	Date: 12/21/09	Project No. 13462.002
AMEC Geomatrix		**Figure 5**

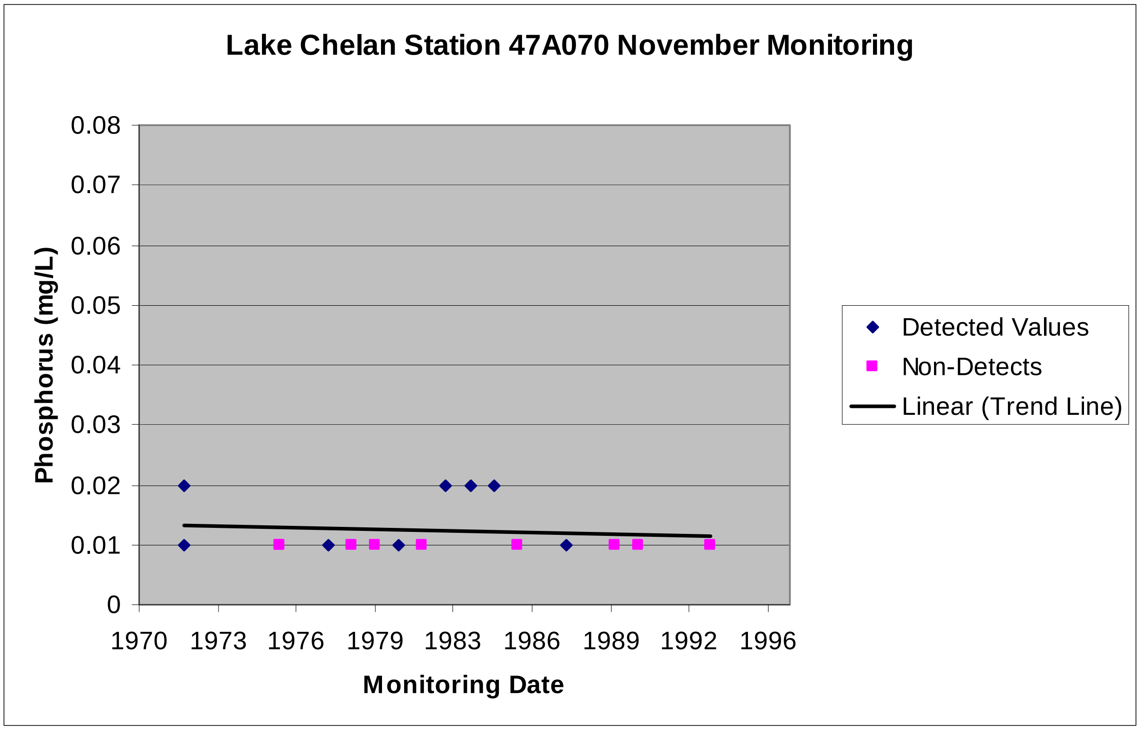


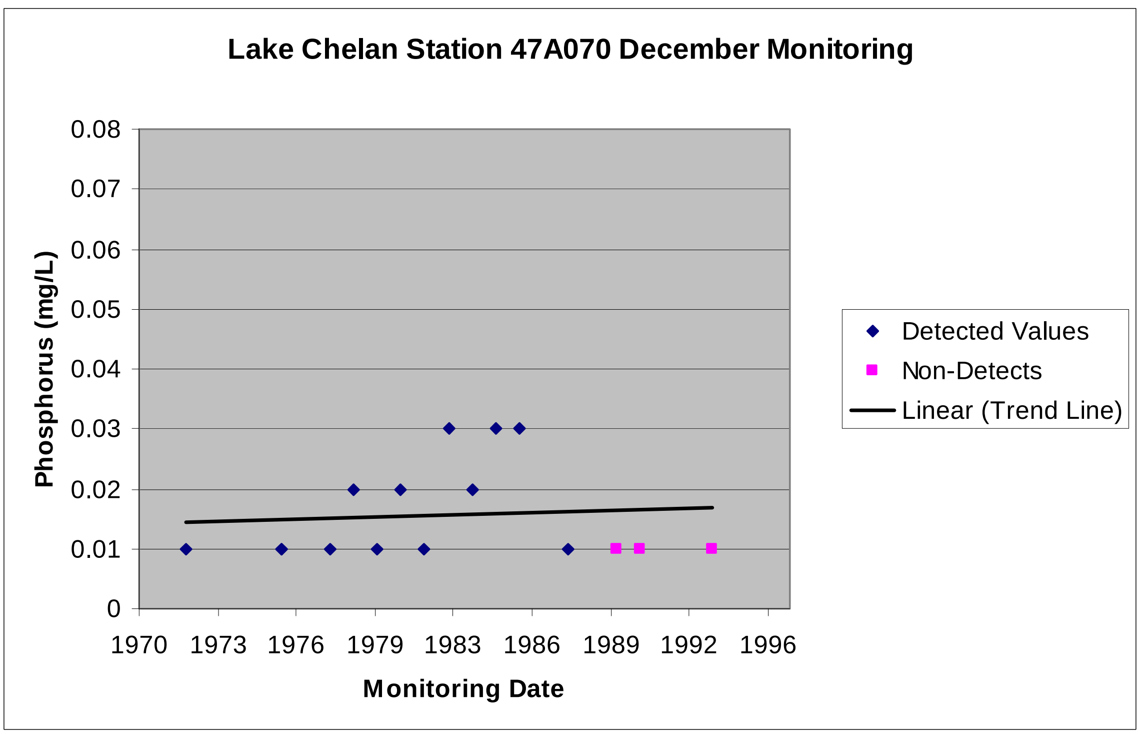


PHOSPHORUS MONITORING
WRIA 47 Phase II Watershed Planning
Chelan County, Washington

By: sge	Date: 12/21/09	Project No. 13462.002
AMEC Geomatrix		Figure 6

Abbreviation(s)
mg/L = milligrams per liter





Abbreviation(s)
mg/L = milligrams per liter

PHOSPHORUS MONITORING WRIA 47 Phase II Watershed Planning Chelan County, Washington		
By: sge	Date: 12/21/09	Project No. 13462.002
AMEC Geomatrix		Figure 7

ATTACHMENT A

WRIA Water Quality Studies Annotated Bibliography

Attachment A
WRIA 47 WATER QUALITY STUDIES ANNOTATED BIBLIOGRAPHY

1. R.W. Beck and Associates. 1982a. Lake Chelan "208" Water Quality Study. Washington State Department of Ecology, Publication No. 82-e12, Olympia.

   This memorandum provides a modified scope of work for a Lake Chelan "208" Water Quality Study. It includes a water balance for Lake Chelan for the years 1976-1980 and nitrogen and phosphorus loads for orchard irrigation returns, Chelan City golf course, Chelan City Park, forest surface runoff, groundwater, precipitation, and dry deposition. The memorandum provides the range of concentrations reported in historical data for water quality parameters (pH, specific conductance, alkalinity, chemical oxygen demand [COD], nitrate+nitrite, ammonia, Kjeldahl nitrogen, total phosphorus, and chlorophyll *a*) in the Wapato Basin, Lucerne Basin, and irrigation drains. The memorandum also summarizes the result of phytoplankton and zooplankton taxonomy analyses conducted for samples collected during August 1969.

2. Devitt, R. 1972. Chelan STP Memo to Tom Hagerty. Washington State Department of Ecology, Publication No. 72-e24, Olympia.

   On July 26, 1972, a standard efficiency survey was conducted on Chelan sewage treatment plant (STP) located on the Chelan River downstream of the Chelan Dam. Composite samples were taken on the influent, primary clarifier effluent, and final effluent. Influent samples were analyzed for temperature conductivity, settleable solids, 5-day biological oxygen demand (BOD), COD, total solids, total nonvolatile solids, total suspended solids (TSS), pH, and turbidity.

3. R.W. Beck and Associates. 1982b. Lake Chelan "208" Water Quality Study. Washington State Department of Ecology, Publication No. 82-e04, Olympia.

   The results of a 1-day (February 24, 1982) monitoring survey of 12 locations in Lake Chelan is presented in this memorandum. The locations sampled are identified in R.W. Beck and Associates (1982a). The water quality parameters analyzed include nitrate+nitrite, total phosphorus, total coliform bacteria, dissolved oxygen (DO), temperature, pH, conductivity, and secchi depth.

4. Porath, H., and Hodgson, J. 1984. Chelan Sewage Treatment Plant (STP) Class II Inspection (July 26-27, 1983) and, Receiving Water Survey (July 27, 1983 and October 26, 1983). Washington State Department of Ecology, Publication No. 84-e09, Olympia.

   This memorandum presents the results of a Class II inspection at the Chelan STP along with a limited receiving water quality survey at six stations located downstream of the Chelan Dam in the Chelan River. The receiving water study in the Chelan River consisted of a one-time sampling of six stations on July 27, 1983, and a one-time sampling of a series of nine stations on October 26, 1983. Receiving water samples were analyzed for DO, temperature, total chlorine residual, pH, turbidity, conductivity, TSS, COD, ammonia, nitrate, nitrite, orthophosphate, total phosphorus, and fecal coliform bacteria.

5. Kendra, W., and Singleton, L. 1986. Shoreline Survey and Source Inventory of Wapato Basin, Lake Chelan. Washington State Department of Ecology, Publication No. 86-e29, Olympia.

   A shoreline survey of Wapato Basin, Lake Chelan, was conducted April 15-16, 1986. Of the 20 sources sampled, 12 were thought to include irrigation return flows, 3 were likely urban runoff, and 2 were streams draining relatively undeveloped watersheds. A map and description of the sampling sites is provided in this memorandum report. The parameters measured were discharge, specific conductance, nitrate+nitrite, ammonia, total phosphorus, and fecal coliform bacteria. Loads to Lake Chelan were calculated and presented in the report.

6. Patmont, C.R., Pelletier, G.J., Welch, E.B., Banton, D., and Ebbesmeyer, C.C. 1989. Lake Chelan Water Quality Assessment, Final Report. Prepared by Harper-Owes, Seattle, Washington, for Washington State Department of Ecology, Olympia.

   The three primary objectives of this investigation were:

   - Provide a baseline study of the lake;
   - Evaluate the suitability of on-site wastewater disposal systems (septic tanks and drain fields) within the developing Lower Chelan Basin; and
   - Estimate principal sources and potential impacts of bacteria and chemicals of concern to Lake Chelan.

Investigators obtained more than 100,000 data observations between November 1986 and November 1987. These observations resulted from the following activities:

- Data compilation and mapping of the near-surface geology and hydrogeology;
- Installation of 23 groundwater monitoring wells;
- Quarterly water quality sampling and analysis of groundwater wells and existing domestic wells;
- Monitoring of hydrologic, chemical, and bacteriological inputs to Lake Chelan from a range of sources through 13 surveys;
- Nearly continuous monitoring of circulation processes;
- Intensive investigations of lake productivity and nearshore algal accumulation, in addition to a bacteriological assessment from three studies; and
- Lake sediment and fish tissue samples (14 each) collected for chemical analysis.

7. Rector, J., and Hallock, D. 1993. Lake Water Quality Assessment Report, 1990. Washington State Department of Ecology, Publication No. 92-124, Olympia.

   This report presents results from the volunteer monitoring program in 48 Washington State lakes, including Lake Chelan. Volunteers monitored Lake Chelan at the center of the lake between Twenty-Five Mile Creek and Dutch Harbor. Temperature, pH, water color, and secchi disk data were collected on June 14, July 11, August 20, and September 6, 1990. A depth profile from the surface to a depth of 50 meters is presented in the report for August 20, 1990. In addition to the above parameters, DO and conductivity were measured for the depth profile.

8. Hopkins, B. 1993. Freshwater Ambient Monitoring Report for Water-Year 1991. Washington State Department of Ecology, Publication No. 93-75, Olympia.

   From October 1, 1990, to September 30, 1991 (Water-Year 1991), the Washington State Department of Ecology (Ecology) Ambient Monitoring Section measured conventional water quality parameters monthly at 81 stations in Washington State. One station (Chelan River @ Chelan) was located within WRIA 47. The parameters measured were ammonia, DO, nitrate+nitrite, pH, orthophosphate, total phosphorus, conductivity, temperature, TSS, turbidity, and fecal coliform bacteria.

9. Hallock, D., and Ehinger, W. 1995. River and Stream Ambient Monitoring Report for Wateryear 1994. Washington State Department of Ecology, Publication No. 95-349, Olympia.

   As part of Ecology's ambient monitoring program monthly water quality data was collected during 1994 at one location within WRIA 47. This location (Station No. 47A070) is described as Chelan River @ Chelan. It is located on the north side of the Woodin Avenue Bridge that crosses Lake Chelan. The water quality parameters monitored included conductivity, DO, pH, temperature, TSS, turbidity, fecal coliform bacteria, soluble reactive phosphorus, total phosphorus, ammonia, nitrate+nitrite, and total nitrogen.

10. Davis, D. 1996. Washington State Pesticide Monitoring Program: 1994 Surface Water Sampling Report. Washington State Department of Ecology, Publication No. 96-305, Olympia.

    This report includes water quality data collected during April, June, and October 1994 at one location (Stink Creek) in WRIA 47. Water samples were analyzed for 161 pesticides and pesticide breakdown products, total organic carbon (TOC), TSS, nitrate+nitrite, conductivity, temperature, pH, and flow. Eleven pesticides were detected in Stink Creek during 1994.

11. Ehinger, W., Cusimano, R., Davis, D., Garrigues, R., and Golding, S. 1995. Watershed Briefing Paper for the Wenatchee Basin Water Resource Inventory Area. Washington State Department of Ecology, Publication No. 95-348, Olympia.

    This briefing paper includes a discussion of water quality issues within Lake Chelan, First Creek, Mitchell Creek, Railroad Creek, and the Stehekin River in WRIA 47. No data are provided in the report.

12. Sargent, D. 1997. Water Quality in the Wapato Basin of Lake Chelan, Summer 1996. Washington State Department of Ecology, Report No. 97-323, Olympia.

Project Objectives:

- Determine the mean epilimnetic total phosphorus (TP) concentration in the Wapato Basin for comparison to previous data and the TMDL criterion of 4.5 µg/L TP.

- Gather information on other key water quality parameters in the Wapato Basin that might indicate degradation of water quality.

Water samples were taken from four stations in the Wapato Basin at the same locations as the 1995 sampling. A hand-held Global Positioning System (GPS) device was used to help locate the sampling stations. At Stations 2, 3, and 4 samples were obtained from three depths, 0.3, 10, and 20 m, and at Station 1 samples were obtained at 0.3 m only. The lake was sampled during seven surveys on the following dates: May 16, June 4, June 20, July 18, August 15, September 9, and October 3, 1996. Samples were analyzed for total phosphorus, total persulfate nitrogen, nitrate+nitrite, chlorophyll *a*, and phaeophytin *a*. Sample duplicates were collected in accordance with the Quality Assurance Project Plan (QAPP). Field measurements for temperature, conductivity, pH, and DO were taken to a depth of 50 m where possible. Secchi disk readings were obtained at each station.

13. Johnson, A., White, J., and Huntamer, D. 1997. Effects of Holden Mine on the Water, Sediments, and Benthic Invertebrates of Railroad Creek, Lake Chelan. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Publication No. 97-330, Olympia.

An initial survey was conducted on June 12 to inspect the Holden Mine site, locate monitoring stations, obtain initial water quality data, and perform qualitative sampling of benthic invertebrates. Water samples were collected at the downstream end of the mine portal discharge (P-5), mouth of Copper Creek (CC-1), and the three Railroad Creek monitoring stations (RC-1 near the wilderness boundary, RC-2 below the tailings piles, and RC-3 at Lucerne). RC-2 has historically been located on the left bank directly opposite the downstream end of tailings pile #3. To allow more thorough mixing of the leachate, Ecology samples were collected approximately 100 yards farther downstream. A sample of the leachate was taken from the east side of tailings pile #3. All water samples were simple grabs; the creek samples coming from the center channel.

Samples were analyzed for a range of conventional water quality parameters, cyanide, and metals. Metals analyzed included those in the Forest Service monitoring program (zinc, copper, iron, and lead); other metals shown to be elevated in U.S. Geological

Survey samples of Holden Mine discharges (iron, aluminum, manganese, cadmium, and nickel); and arsenic, mercury and silver.

14. Anchor Environmental, LLC. 2000. 1999 Water Quality Monitoring Report, Final: Lake Chelan Hydroelectric Project, FERC Project No. 637. Prepared for Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Water quality monitoring was conducted during 1999 at eight stations in WRIA 47: five in Lake Chelan, one at the lake outlet, one in the lower bypass reach, and one in the tailrace. Of the five stations in Lake Chelan, four were in the Wapato Basin and one was in the Lucerne Basin. Sampling stations occupied in the Wapato Basin were located at the same coordinates sampled in 1987 (Patmont et al., 1989), 1995 (Congdon, 1996), and 1996 (Sargeant, 1997). The 1999 Lucerne Basin station was positioned sufficiently uplake of the Wapato Basin to minimize the potential for mixing between these two basins; this station location is representative of water quality conditions in the Lucerne Basin.

The lake outlet station was located at the Riverwalk Park boat ramp on Lake Chelan, approximately 500 feet uplake from the dam. The lower bypass reach station was located just below the gorge section of the reach. In this way, water quality was characterized just before entering the bypass reach and again immediately after traveling through the turbulence and plunging of the gorge section. Data collected from these stations provide a characterization of maximum water quality changes within the bypass reach. The tailrace station (T1) was located approximately 200 feet downstream of the powerhouse to characterize water quality conditions of water passing through the power generating system of the project.

At the five stations in Lake Chelan, water quality was measured at the surface (0.3 m), and at 10 m, 20 m, 70 m, and 100 m, where possible. To characterize water quality at each depth, the following parameters were measured: temperature, DO, pH, conductivity, TP, total nitrogen, and nitrate+nitrite. At each station, total dissolved gas and water transparency were measured at the surface and chlorophyll *a* was measured at the surface, and at 10 m and 20 m. At the bypass reach and tailrace stations, surface measurements (0.3 m) of temperature, DO, pH, conductivity, total dissolved gas, and TSS were recorded.

Sampling was conducted eight times between the start of May and the end of September 1999. Due to weather constraints, the Lucerne Basin station was only sampled during five of the eight sampling events. Due to the absence of water in the

bypass reach, the lower bypass reach station (B2) was only sampled during June through August; the bypass reach was not sampled during the May or September sampling events.

15. Burgoon, P., and Cross, P. 2004. Manson Lakes Water Quality Assessment: Lake Trophic Status and DDT and Phosphorus Load Evaluation. Prepared for Washington State Department of Ecology, Olympia.

This project summarizes results from a two-year program that monitored DDT and phosphorus loads into the Manson Lakes (Roses, Dry, and Wapato lakes). Net storage of DDT and phosphorus in the lakes was determined as well as the loads exported from Manson Lakes into Lake Chelan. Lake water samples were collected monthly at two stations in each lake from March to December in 2002 and from February to May in 2003. Stations were located along a center line on the long axis of each lake. Lake samples were analyzed for total phosphorus, orthophosphate, chlorophyll *a*, turbidity, and alkalinity. Agricultural drains were sampled for the above parameters, DO, temperature, pH, nitrate, TSS, and total DDT.

16. Coots, R., and Era-Miller, B. 2003. Quality Assurance Project Plan: Total Maximum Daily Load Study for DDT and PCBs in Lake Chelan. Washington State Department of Ecology, Publication No. 03-03-105, Olympia.

This document is the QAPP for sampling to support the Lake Chelan DDT and PCBs in fish TMDL. Existing data (prior to 2003) on PCB and DDT compounds in fish, sediments, and water are provided in the QAPP. This TMDL technical study will determine what DDT and PCB loading to Lake Chelan and Roses Lake will result in edible fish tissue meeting EPA human health criteria for 4,4’-DDE, PCB-1254, and PCB-1260. Sampling will occur in the Wapato and Lucerne basins of Lake Chelan, Manson Lakes, and tributaries and irrigation drains that discharge into Lake Chelan.

17. Coots, R., and Era-Miller, B. 2006. Lake Chelan DDT and PCBs in Fish Total Maximum Daily Load Study. Washington State Department of Ecology, Publication No. 05-03-014, Olympia.

This report describes the water, sediment, and fish tissue analyses conducted to support the TMDL for PCBs and DDT in fish within Lake Chelan. Five water surveys of Lake Chelan tributaries and irrigation drains were conducted between May and November 2003. The tributaries sampled included First Creek, Knapp Coulee, Purtteman Creek, Joe Creek, Stink Creek, Twenty-Five Mile Creek, Prince Creek,

Railroad Creek, and the Stehekin River. Six irrigation drain discharges to the Wapato Basin were also sampled along the north shore of Lake Chelan. The only surface water samples collected from Lake Chelan were from the Riverwalk Park Boat launch near the lake outlet.

Water concentrations of DDT compounds were also estimated from three deployments of semi-permeable membrane devices (SPMDs) during May-June, July-August, and October-November 2003 off Wapato Point (Wapato Basin) and Twenty-Five Mile Creek (Lucerne Basin). The original data published in June 2005 were revised during December 2006 due to the discovery of calculation errors that overestimated DDT concentrations by at least a factor of five.

Sediment samples (top 2 cm) were collected at 15 locations along a transect located in the middle of the Wapato and Lucerne basins and analyzed for DDT, DDE, DDD, total PCBs, TOC, and grain size. Two sediment cores were also collected (one from each basin) and analyzed for DDT compounds and total PCBs for 1 cm increments to a depth of 10 cm. The sediment strata were dated using lead-210 and cesium-137 markers.

Approximately 200 fish were collected during 2003 and analyzed for DDT compounds, Aroclor PCBs, and total lipid for this study. The species analyzed included lake trout, burbot, kokanee, and rainbow trout.

18. Seiders, K., Deligeannis, C., and Kinney, K. 2006. Washington State Toxics Monitoring Program: Toxic Contaminants in Fish Tissue and Surface Water Environments, 2003. Washington State Department of Ecology, Publication No. 06-03-019, Olympia.

    This report provides the results of chemical analyses for mercury, total PCB, and DDT compounds in composite samples of largemouth bass collected during 2003 in Roses Lake. No water quality samples were collected in Roses Lake.

19. Schneider, D., and Coots, R. 2006. Lake Chelan Watershed DDT and PCB Total Maximum Daily Load: Water Quality Improvement Report. Washington State Department of Ecology, Publication No. 06-10-022, Olympia.

    This report was prepared after the *Lake Chelan DDT and PCBs in Fish Total Maximum Daily Load Study*, and was intended to provide EPA with an assessment of DDT, PCB, and other pollutants identified for the TMDL for Lake Chelan. The report provides a description of identified sources of pollutants, loads, and reductions needed to meet federal and Washington State water quality standards. Actions to reduce current pollutant loads and monitoring to document the eventual attainment of water quality standards are recommended in the report.

The description of the water column DDT concentrations estimated by the use of SPMDs on page 15 of the report is not accurate. The discussion is based on values published in 2005. The results were revised in December 2006 to correct calculation errors which reduced the estimated concentrations by at least a factor of five. The recommended load reductions are not affected by the changes in the SPMD data.

20. Johnson, A., and Seiders, K. 2005. Quality Assurance Project Plan. PBT Monitoring: Measuring PBDE Levels in Washington Rivers and Lakes. Washington State Department of Ecology, Publication No. 05-03-113, Olympia.

This QAPP describes a study to be conducted during 2006 to analyze fish tissue and water samples for 10 congeners that occur within commercial polybrominated diphenyl ether (PBDEs) products.

Specific study objectives were:

- Measure PBDE concentrations in three fish species from each of 20 waterbodies;
- Analyze composite fillet samples and limited numbers of whole fish composites;
- Measure PBDE concentrations in water samples from each of 10 representative fish collection sites;
- Assess seasonal changes in water column PBDE levels at six sites;
- Rank the waterbodies in terms of the level of PBDE contamination;
- Identify spatial, species, and temporal patterns in the environmental distribution and accumulation of PBDEs; and
- Lake Chelan was proposed as one of the sampling locations for this study.

21. Johnson, A., Seiders, K., Deligeannis, C., Kinney, K., Sandvik, P., Era-Miller, B., and Alkire, D. 2006. PBDE Flame Retardants in Washington Rivers and Lakes: Concentrations in Fish and Water, 2005-2006. Washington State Department of Ecology, Publication No. 06-03-027, Olympia.

This report includes the result of a study to analyze fish tissue and water samples for the predominant PBDE congeners found in commercial flame retardant products. Lake Chelan was among 10 lakes selected for this study. Water concentrations were estimated using SPMDs; however, Lake Chelan was not among the three lakes where water concentrations were estimated.

Composite fish fillets from Lake Chelan cutthroat trout and kokanee were analyzed for PBDEs and lipid. PBDE 99 was the only congener detected in cutthroat trout, with a total PBDE concentration of 0.14 µg/kg. Three congeners (PBDE 99, 153, and 154) were detected in kokanee with a total PBDE concentration of 1.0 µg/kg. The concentration of PBDE in Lake Chelan fish ranked 41 out the 44 (rank 1 is highest) lake and river locations sampled for this study.

22. Geomatrix Consultants, Inc. 2007. DDT Concentrations in Lake Chelan Waters Measured Using Semipermeable Membrane Devices (SPMDs) and a Large-Volume Solid-Phase Extraction Device. Prepared for Chelan County Natural Resource Department, Wenatchee, Washington.

DDT concentrations were measured in deeper waters off Wapato Point at approximately the same location sampled by Ecology during 2003 using two independent sampling technologies that are well established for measuring trace concentrations of organic chemicals. Two arrays of SPMDs, which provide an estimate of the average dissolved chemical concentration over the period of deployment, were anchored in place approximately 20 feet above the sediment surface and at a water depth of 200 feet.

The Infiltrex 300, which is a large-volume solid-phase extraction device developed by Axys Technologies Inc. was used to filter large volumes of water through an XAD resin column which retains both dissolved and particulate DDT for analysis. Use of this instrument provides a point estimate of DDT concentration. Infiltrex samples were collected at the same location and depth as the SPMDs, just prior to their deployment and retrieval. The average dissolved DDT concentration in water processed with the Infiltrex 300 was compared to the average dissolved DDT concentration estimated from the SPMDs.

Dissolved and particulate DDT concentrations above and below the thermocline off Wapato Point were assessed by collecting near-surface and deepwater samples using the Infiltrex 300. The Infiltrex 300 was also used to collect surface water samples off

Riverwalk Park to compare DDT concentrations in this location with near-surface values observed off Wapato Point.

23. Sargeant, D. 2007. Quality Assurance Project Plan: Lake Chelan Wapato Basin Total Phosphorous TMDL Effectiveness Monitoring, 2007. Washington State Department of Ecology, Publication No. 07-03-109, Olympia.

    This QAPP describes the 2007 sampling that was conducted to assess total phosphorus in the Wapato Basin of Lake Chelan. The QAPP indicates that field sampling will occur at four locations during seven events at evenly spaced intervals between May and September 2007. No data are presented in the QAPP. The water quality parameters that will be analyzed include temperature, specific conductivity, pH, DO, chlorophyll *a*, chloride, nitrate+nitrite, total persulfate nitrogen, and total phosphorus.

24. Congdon, G. 1996. Epilimnetic Water Quality in the Wapato Basin of Lake Chelan, Summer 1995. Lake Chelan Water Quality Committee, Wenatchee, Washington.

ATTACHMENT B

Other Studies Conducted Within WRIA 47

Attachment B
OTHER STUDIES CONDUCTED WITHIN WRIA 47

PHYSICAL/GEOLOGICAL/FISH TISSUE/OTHER STUDIES

1. Geomatrix Consultants, Inc. 2006. Wapato Basin Hydrogeologic Characterization, Lake Chelan TMDL Support Project, Chelan County, Washington. Prepared for Chelan County Natural Resources Program, Wenatchee, Washington.

2. Washington State Department of Ecology. 1996. Washington State Pesticide Monitoring Program: 1994 Fish Tissue and Sediment Sampling Report. Ecology, Publication No. 96-352, Olympia.

3. Seiders, K., Deligeannis, C., and Kinney, K. 2006. Washington State Toxics Monitoring Program: Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2003. Washington State Department of Ecology, Publication No. 06-03-19, Olympia.

4. Kendra, W., and Singleton, L. 1987. Morphometry of Lake Chelan. Washington State Department of Ecology, Publication No. 87-1, Olympia.

5. Hopkins, B.S., Clark, D.K., Schlender, M., and Stinson, M. 1985. Basic Water Monitoring Program: Fish Tissue and Sediment Sampling for 1984. Washington State Department of Ecology, Water Quality Investigations Section, Publication No. 85-7, Olympia.

6. Johnson, A. 1997. Wapato Lake – Pesticides Levels, Sediment Bioassays, and Abundance of Benthic Invertebrates. Washington State Department of Ecology, Publication No. 97-e05, Olympia, http://www.ecy.wa.gov/biblio/97e05.html (accessed December 22, 2009).

7. Pine, R. 1967. The Effects of the Holden Mine Tailings upon the Aquatic Insect Fauna of Railroad Creek, a Tributary to Lake Chelan. State of Washington, Water Pollution Control Commission, Publication No. 67-e00, Olympia.

8. Federal Energy Regulatory Commission (FERC). 2002. Preliminary Draft Environmental Assessment for Hydropower License: Lake Chelan Hydroelectric Project, FERC Project No. 637, Washington. FERC, Office of Energy Projects, Washington, D.C., http://www.chelanpud.org/relicense/ (accessed November 7, 2007).

9. Federal Energy Regulatory Commission (FERC). 2003. Final Environmental Assessment for Hydropower License, Lake Chelan Hydroelectric Project, FERC Project No. 637, Washington. FERC, Office of Energy Projects, Washington, D.C.

10. Public Utility District No. 1 of Chelan County. 2001. Stehekin River Sedimentation Summary, Final: Lake Chelan Hydroelectric Project, FERC Project No. 637. Chelan County, Wenatchee, Washington.

11. Geomatrix Consultants, Inc. 2007. Sediment Organochlorine Pesticide Concentrations in the Vicinity of Tributary and Irrigation Drain Discharges to Lake Chelan, Lake Chelan TMDL Support Project, Chelan County, Washington. Prepared for Chelan County Natural Resource Department, Wenatchee, Washington.

12. U.S. Environmental Protection Agency (EPA). 2004. National Study of Chemical Residues in Lake Fish Tissue: Year 1 and Year 2 Data. Office of Water, Office of Science and Technology, EPA-823-C-04-006 (Year 1) and EPA-823-C-04-007 (Year 2), Washington, D.C.

13. Serdar, D., Johnson, A., and Davis, D. 1994. Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Publication No. 94-154, Olympia.

14. Serdar, D. 2005. Quality Assurance Project Plan: Bioaccumulative Chemicals in Hatchery Feed and Hatchery Fish. Washington State Department of Ecology, Publication No. 05-03-104, Olympia.

15. Davis, D., and Johnson, A. 1994. Washington State Pesticide Monitoring Program: Reconnaissance Sampling of Fish Tissue and Sediments (1992). Washington State Department of Ecology, Publication No. 94-194, Olympia.

TABLE

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**12**	**13**	**14**	**15**	**17**	**22**
Water Quality Parameter	**Units**																	
Conventionals																		
Alkalinity	mg CaCO3/L	●					●							●		●		
Ammonia	µg N/L	●			●	●	●		●	●								
Bicarbonate	µg/L						●											
Biological Oxygen Demand	mg/L		●															
Chemical Oxygen Demand	mg/L	●	●		●													
Chloride	mg/L						●											
Chlorophyll a	µg/L	●					●					●	●		●	●		
Cyanide	mg/L													●				
Dissolved Oxygen	mg/L			●			●	●	●	●		●	●		●	●		
Dissolved Oxygen Saturation	%						●						●					
Fluorine	µg/L						●											
Light Extinction Coefficient	1/meter						●											
Nitrogen - Nitrite+Nitrate N	µg N/L	●		●	●	●	●		●	●	●	●	●	●	●	●		
Nitrogen - Total N	µg N/L	●			●		●			●					●			
Nitrogen - Total Persulfate N	ng/L											●	●					
Nitrogen - Total Soluble N	µg N/L						●											
pH		●	●	●	●		●	●	●	●	●	●	●	●	●	●		
Phaeophytin	µg/L						●					●	●					
Phosphorus - Orthophosphate	mg/L				●				●							●		
Phosphorus - Soluble Reactive P	µg P/L						●			●								
Phosphorus -Total P	µg P/L	●		●	●	●	●		●	●		●	●	●	●	●		
Phosphorus - Total Soluble P	µg P/L						●											
Secchi Disk Depth	meters			●			●	●				●	●					
Specific Conductance	µmho/cm	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
Sulfate	mg/L													●				
Temperature	°C		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●
Total Chlorine Residual	mg/L				●													

P:\Chelan County\13462-002 WRIA 47 Phase II Watershed Planning\3000 REPORTS\Long-TermMonPlanRevised\Appendix B\Table 1_sge rev.xls

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		1	2	3	4	5	6	7	8	9	10	24	12	13	14	15	17	22
Water Quality Parameter	**Units**																	
Conventionals (continued)																		
Total Dissolved Gas	%														●			
Total Hardness	mg/L													●				
Total Nonvolatile Suspended Solids	mg/L		●															
Total Organic Carbon	mg/L										●						●	
Total Solids	mg/L		●															
Total Settleable Solids	mg/L		●															
Total Suspended Solids	mg/L		●		●		●		●	●	●			●	●	●	●	
Total Nonvolatile Suspended Solids	mg/L		●															
Transparency															●			
Turbidity	NTU		●		●		●		●	●				●		●	●	
Bacteria																		
Fecal Streptococci	#/100 mL						●											
Fecal Coliform	#/100 mL		●		●	●	●		●	●		●						
Total Coliform	#/100 mL			●			●											
Metals																		
Aluminum	µg/L						●							●				
Arsenic	µg/L						●							●				
Cadmium	µg/L													●				
Calcium	µg/L						●											
Copper	µg/L													●				
Iron	mg/L						●							●				
Lead	µg/L													●				
Managanese	µg/L													●				
Mercury	µg/L													●				
Nickel	µg/L													●				
Silver	µg/L													●				
Zinc	µg/L													●				

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**24**	**12**	**13**	**14**	**15**	**17**	**22**
Water Quality Parameter	**Units**																	
Herbicides																		
2,4-D	µg/L										○							
Atrazine	µg/L										○							
Bromacil	µg/L										○							
Bromoxynil	µg/L										●							
Dacthal	µg/L										○							
Dichlorobenil	µg/L										●							
Dichlofop-methyl	µg/L										○							
MCPA	µg/L										○							
MCPP	µg/L										○							
Norflurzaon	µg/L										●							
Norflurazon Desmethyl	µg/L										●							
Simazine	µg/L										●							
Trillate	µg/L										○							
Insecticides																		
Carbaryl	µg/L										○							
Chlorpyrifos	µg/L										●							
4,4'DDD	ng/L															●	●	●
4,4'DDE	ng/L										○					●	●	●
4,4'DDT	ng/L										●					●	●	●
Total DDT	ng/L										●					●	●	●
Diazinon	µg/L										●							
Diuron	µg/L																	
Hexazinone	µg/L																	
3-hydroxycarbofuran	µg/L										●							
Malathion	µg/L										○							
Ozinphos-methyl (Guthion)	µg/L										●							
Terbacil	µg/L																	

TABLE 1

WATER QUALITY PARAMETERS ANALYZED WITHIN WRIA 47

Chelan County, Washington

Data Collection Period		1969-1980	1972	1982	1983	1986	1986-1987	1990	1991	1994	1994	1995	1996	1996	1999	2002-2003	2003	2006
SOURCE [1]		1	2	3	4	5	6	7	8	9	10	24	12	13	14	15	17	22
Water Quality Parameter	**Units**																	
Other Organics																		
Bromodichloromethane	µg/L						●											
Chlorodibromomethane	µg/L						●											
Pentachlorophenol	µg/L										●							
PCB Aroclors	µg/L																●	
PCB Congeners	µg/L																	
Tribromomethane	µg/L						●											
Trichloromethane	µg/L						●											

Note(s)

1. See Attachment A for Source references.

● Analyzed Parameter

O Analyzed parameter but not detected

Appendix C
Habitat Component

Chelan County
Grant No. G0700224

LAKE CHELAN WRIA 47 Watershed Management Plan:
Phase III Habitat Component

Prepared for:

Chelan County
Natural Resources Department
316 Washington Street, Suite 401
Wenatchee, Washington 98801

Prepared by:

750 Sixth Street South
Kirkland WA 98033

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March 2011

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LAKE CHELAN WRIA 47 WATERSHED MANAGEMENT PLAN HABITAT COMPONENT

1. INTRODUCTION

This attachment is intended to provide detailed information in supplementation of the Lake Chelan WRIA 47 Watershed Planning, Phase III report. It represents a summary of existing information and analyses pertaining to aquatic habitat in the Chelan Watershed, including previous planning efforts; existing aquatic resources and impacts; and management goals, recommendations, and strategies.

2. EXISTING WATERSHED ANALYSIS, HABITAT ASSESSMENT, AND SPECIES STATUS INFORMATION

The process of watershed planning includes a review of all existing information so that gaps in knowledge and research can be identified. Where knowledge does exist, a thorough review of all past work is needed to weigh the relative importance of habitat restoration goals in the watershed, and to assess the need for project and action implementation in order to fulfill these goals.

Habitat assessment and restoration in the Lake Chelan Watershed have been the focus of past and ongoing efforts led by Chelan County and other entities. The following studies and documents include analyses of aquatic habitat components, watershed processes, fish species occurrence and use, and other habitat features or components.

2.1 WRIA 47 Watershed Planning

The 1998 Watershed Planning Act (RCW Chapter 90.82) provides funding and structure for locally-based watershed planning in each WRIA. Planning units comprising members from a broad field of water-use interests are formed to guide the planning process. The WRIA 47 planning unit formed in 2007 to oversee technical studies designed to fill data gaps in water resource issues in the Lake Chelan Watershed, as well as to develop and implement strategies that address identified issues.

Watershed planning is divided into four phases. Chelan County, the City of Chelan, and the Lake Chelan Reclamation District applied for Phase I funding from the Washington Department of Ecology (Ecology) and Chelan County, the lead entity in the process, received a grant of $50,000 to initiate the first planning phase, Organization. A number of interested parties, including the Colville Confederated Tribes, Yakama Nation, Cascadia Conservation District, the Chelan River Irrigation District, and others expressed interest in participating in the planning process.

One mandatory and three optional elements are the focus of watershed planning. The planning unit selected the optional element of water quality for inclusion, with the mandatory water quantity component, in Phase I watershed planning. The optional elements of instream flow and habitat were omitted because they had been addressed to some extent in previous efforts. Phase I was completed in January 2008. Phase II, Assessment, resulted in the documents introduced below in Sections 2.1.2 and 2.1.3. Phase II was completed in January 2009.

2.1.1 Lake Chelan Planning Unit Charter

The Lake Chelan Planning Unit Charter (RH2 Engineering, Inc. and AMEC Geometrix, Inc. 2007) defines the planning unit's mission, goals, objectives, and strategies for protecting the aquatic resources of the Lake Chelan Watershed. The Charter states as its vision "to recognize, inform, educate, monitor, understand and protect the unique water resource that is Lake Chelan; the ecological processes and pathways essential to maintaining this high quality water body, and the ways in which we can live on this lakeshore, enjoy this unique treasure and protect it for generations to come." The document outlines the organization, roles and responsibilities of each entity participating in WRIA 47 watershed planning under the Watershed Planning Act (RCW 90.82).

2.1.2 Phase II Water Quantity Assessment, WRIA 47: Lake Chelan

This Phase II Water Quantity Assessment (RH2 Engineering, Inc. 2009) is a comprehensive characterization and assessment of the water supply in WRIA 47. It includes analyses of surface and ground water, including seasonal, climatic, and other variations; an estimate of water represented by claims, permits, instream flow rules, and other rights; estimated present and future water use and availability; and identification of aquifers and aquifer recharge areas.

2.1.3 Long-term Water Quality Monitoring for Lake Chelan

Phase II Watershed Planning for WRIA 47 included identifying all potentially impaired waterbodies in the Lake Chelan Watershed for parameters on the Clean Water Act 303(d) list. The work included completion of the Long-Term Monitoring Plan for Lake Chelan (AMEX Geometrix, Inc. 2009), which identifies goals addressing water quality and data gaps, as well as providing recommendations for methods to achieve long-term water quality monitoring objectives.

2.2 Lake Chelan Fishery Plan (FERC Project No. 637)

The Federal Energy Regulatory Commission (FERC) project license for the Lake Chelan Hydroelectric Project No. 637 includes Article 404, which required the Chelan PUD to complete a fishery plan for Lake Chelan in 2007. The plan is intended to demonstrate compliance with efforts to restore and enhance native fisheries in Lake Chelan and its tributaries while supporting a recreational fishery. The Lake Chelan Fishery Plan (LCFP) (Chelan County PUD 2007) includes an overview of historical and current occurrence of fish species in Lake Chelan and its tributaries. It addresses habitat factors impacting the species' success at various life stages, as well as other information related to the success of each species, including the results of recent creel surveys and tributary studies, status as recreational and commercial species, hatchery input, and known species interactions. The LCFP also provides an implementation plan and schedule for developing a food web model for the lake and tributaries, implementing a monitoring and evaluation program, removing fish barriers from the mouths of tributaries to the lake, stocking fish, measuring entrainment, and collecting large woody debris.

2.3 Lake Chelan Sub-basin Plan (LCSP)

This Chelan County-led effort was conducted with the oversight of the Upper Columbia Salmon Recovery Board (UCSRB), which includes representatives from Chelan, Douglas, and Okanogan Counties; the Yakama Nation; and the Colville Confederated Tribes. Public involvement in the plan was largely via Chelan PUD during the FERC relicensing process for the Lake Chelan Hydroelectric Project No. 637, in which landowners, agricultural interests, private businesses, tourism and recreation industries, environmental groups, resource and other governmental agencies, Indian tribes, and County citizens participated through meetings, working groups, newsletters, and presentations.

The 2007 Sub-basin Plan (Laura Berg Consulting 2004) describes the topography, geology, climate, vegetation, and soil characteristics of the Lake Chelan sub-basin (WRIA 47). Fish and wildlife resources, habitat types and conditions, and focal species and habitats are presented in detail.

2.4 Draft In-Lieu Fee (ILF) Prospectus Program Prospectus and Compensation Planning Framework for Lower Lake Chelan, Chelan County

CCNRD is sponsoring the proposed In-Lieu Fee (ILF) Program for lower Lake Chelan under an April 10, 2008 final rule governing compensatory mitigation authorized under Department of the Army permits issued under Section 404 of the Clean Water Act. The ILF Program process begins with completion of the draft Prospectus, which includes an analysis of the service area. The framework element of the draft Prospectus (The Watershed Company 2010) describes the natural conditions of the Wapato sub-basin. Because one purpose of the ILF Program is to provide a mitigation alternative for projects that have unavoidable impacts on aquatic resources, the framework includes an analysis of historic and present habitat-related resources in the sub-basin. The analysis determines aquatic habitat components that would improve watershed health if restored, as well as identifying locations for potential restoration projects.

3. Summary of Resources and Habitat Impacts in the Lake Chelan Watershed

Issues identified and addressed in past studies in the Lake Chelan Watershed concern management of fish species to promote healthy populations, support recreational fisheries, and monitor management actions. Factors impacting fish populations in the watershed include habitat degradation and loss, passage barriers, dam operations, flooding, species introductions, interspecific breeding, competition for resources, predatory relationships, disease, harvest, and hatchery and stocking operations.

3.1 Hydrology and Water Storage

The natural hydrology of Lake Chelan is altered by dam operations. Construction of the Lake Chelan Hydroelectric Project raised the elevation of the lake by 21 ft (6.4 m), flooding the surrounding land (from Chelan Chamber of Commerce, http://www.lakechelan.com/551.html). Although the current licensing agreement permits the operation of the lake operated between of 1,100 ft (335 m) above sea level and a minimum elevation of 1,079 ft (329 m), it has never been drawn down to the minimum level (Schneider and Coots 2006). The average minimum lake elevation is 1,086 ft (331 m) above sea level (http://www.chelanpud.org/lake-chelan-lake-levels.cfm), and operation between June and September is designed to keep the lake elevation at or above 1,098 ft (334 m) whenever possible. An historic high-water event was recorded in June 1894, when the water level was reportedly raised to 11 ft (3.4 m) above the 1892 water level (influenced by an 1889 dam) (Hillman and Giorgi 2000). Flooding in the Stehekin River and Railroad Creek and unusual debris flows in several other creeks indicate a possible increase in frequency and magnitude of floods (Montgomery Group et al. 1995).

Vegetation alteration also has the potential to affect hydrology and water storage in the watershed. Forest changes have resulted in the single largest impact in the Chelan Watershed, affecting most of the watershed at various points in time.

Harvested slopes alter surface water hydrology by producing flashy stream flows (i.e., high but short duration peak flows) and increasing erosion and deposition. However, timber forest was a more significant impact historically, and fire is the primary agent of forest changes in the watershed presently. Widespread fire suppression in the basin and the resultant fuel loads allowed for greatly increased fire severity beginning in the late 1960s. Recent severe fires have caused loss of mature vegetation, further impacting water storage and flow in the watershed.

The cumulative effect of insects, pathogens, noxious weeds, and grazing on overstory and large trees also impacts hydrology indirectly by affecting fire regime. Insects, including mountain pine beetle (*Dendroctonus ponderosae*), bark beetle, and spruce budworm (*Choristoneura occidentalis*), produce heavy fuel loads. Similarly, cheatgrass, facilitated by mostly historic grazing, sets seed earlier than most native species, out-competing them and creating an early fuel source for fire. Other invasive terrestrial plant species with low soil-holding capacities have increased spring soil moisture use as well, drying out and degrading conditions for native plants. Grazing impacts are limited because of the unsuitability of much of the watershed's steep slopes and the discontinued permitting on USFS land in the late 1990s, but past grazing in the forests compacted soils and instigated non-native plant invasions, affecting conditions that persist today.

The impacts of shoreline armoring on hydrology are closely related to habitat impacts and are addressed in the main body of the Lake Chelan Watershed Plan.

3.2 Water Quality

Water quality is addressed in detail in main body of the Lake Chelan Watershed Plan. It is included here only as it impacts aquatic habitat in the watershed.

The erosion and sedimentation precipitated by the fire-driven deforestation described in the preceding section impacts water temperature and turbidity, potentially affecting fish and fish habitat. Pesticides are another area of concern in Lake Chelan. DDT is a chlorinated pesticide that was widely used on orchards in the basin from the 1940s, when DDT was developed, until 1972 when it was banned in the U.S. (Schneider and Coots 2006). PCBs are chlorinated compounds widely used in industrial applications as coolants, hydraulic fluids, plasticizers, marine paints, and a variety of other applications. No specific source of PCBs has been identified in the basin, but many potential sources exist, including atmospheric deposition. PCBs can volatize easily and travel great distances in the atmosphere, to be deposited in remote locations where they were never used. PCBs were banned in the U.S. in 1979. Both DDT and PCBs are slow to break down in the aquatic environment, which helps to explain their presence in a basin where they have not been used in more than 30 years.

3.3 Aquatic Habitat

In addition to water quality and hydrology effects on habitat, more direct impacts have altered and continue to alter aquatic habitat in the Lake Chelan Watershed. Impacts and affected functions are listed in Table 1.

Loss of riparian vegetation due to repeated high-severity fires impacts stream shading and large woody debris recruitment in addition to the hydrologic and water quality impacts presented in the previous sections. Large woody debris is of particular importance and may be limiting in Lake Chelan because of the ultra-oligatrophic conditions in the lake (Lenz 2008). Habitat complexity and nutrient cycling are both important functions of large woody debris.

The Wapato sub-basin experiences the greatest level of human-caused aquatic impacts in the Lake Chelan Watershed. Development in the sub-basin includes the upland conversion to agriculture, the Lake Chelan Hydroelectric project (dam), shoreline clearing and development, shoreline armoring, and docks and piers. Each of these alterations impacts aquatic habitat and the fish community in the watershed.

Wind is naturally funneled down the valley over Lake Chelan, reaching the Wapato sub-basin with high velocities and aligned with the longest wave fetch. This allows the generation of large waves and concentrates force at the most populated and developed parts of the lake. Bulkheads and other shoreline armoring line much of the lakeshore in the Wapato sub-basin to protect the shoreline from wave erosion and, in some cases, to protect properties developed on artificial fill. Shoreline armoring may divert juvenile salmonids to deeper water, where they are subject to increased predation (Kahler et al 2000). Artificial bank protection also eliminates shallow-water and transitional habitat.

Dam operations in Lake Chelan alter the exposed shoreline and have the greatest impact on hydrology in the lake. Dam operations maintain the highest lake levels between July and September, rather than during spring runoff, as would occur under a natural flooding regime. Higher sustained lake levels prevent sediment from depositing on the lower faces of alluvial fans, concentrating deposition on the upper portion of the fan and creating a broad, relatively flat sill. This sill effect results in a wide, shallow flow at the mouth of the stream, which lacks sufficient depth and creates a barrier to upstream migration. In one study of the lake, six of the nine tributaries surveyed suffered from this sill effect (Duke Engineering Services, Inc. 2000a).

The timing of lake level fluctuations can also be problematic for species using the lake, changing accessibility of nearshore areas as lake level rises and falls. All native fish species in the lake except for cutthroat trout spawn in the nearshore areas, peaking from May through July, and juveniles remain to rear and feed. Current timing of lake fluctuation places rearing and feeding juveniles in the most highly developed lake area in terms of armoring and over-water structures.

Lake Chelan has more than 1 million ft^2, or nearly 72 ac (29 ha), of overwater structures (DNR GIS data (overwater structures); 2007 interpretation of 2002-2006 aerial photographs), including piers, docks, and shoreline fill. The majority of these structures are in the Wapato sub-basin. A comprehensive literature review concerning the impact of over-water structures in freshwater environments (Carrasquero 2001) was conducted and is a source for the summary of impacts presented here.

Overwater structures alter the shore-zone habitat structure, which in turn may alter the fauna and flora assemblages, predator-prey relationships, fish behavior and habitat function. Overwater structures are also often associated with other habitat alterations, including disturbed substrate during construction, altered water movement around structures, installed associated structures like bulkhead and other bank armoring, and increased boat traffic. The overall impact to habitat is a complex interaction of effects that may benefit some species and harm others.

Shoreline armoring has reduced the natural functional value that would be provided by lake-fringe wetlands or vegetation. Bulkheads and other shoreline development have resulted in a highly altered to non-existent shoreline and nearshore vegetation. Natural shoreline vegetation is limited to the Spader Bay area, some properties above Wapato Point, Lake Chelan State Park, and a few other publicly owned parcels on the south shore. Not only does this result in very little overhanging vegetation for aquatic species, but little cover for other wildlife that might use the lake or shoreline. Few lake-fringe wetlands exist, and none are extensive. The present level of armoring and frequency of docks, coupled with the relatively abrupt littoral zone (although milder than the Lucerne sub-basin, it is still considered steep), offers little opportunity to create or restore lake-fringe wetlands.

Both dam operations and shoreline hardening redistribute wave energy, and bulkheads in particular tend to increase wave energy as waves are deflected. This impacts shoreline habitat by promoting erosion of adjacent beaches and alteration of sand and gravel recruitment (Lorang et al. 1993, Mulvihill et al. 1980). The natural accumulation of drift logs, hindered by the increased wave energy, would augment sediment-trapping and protects shorelines from excessive wave action, as well as allowing new riparian habitat to establish and improving the limnetic environment (Lorang and Stanford 1993). The cumulative effects of wave energy changes and exacerbations in the Wapato Secondary sub-basin have not been measured, but they surely have an impact on large woody debris accumulation, riparian vegetation, and shoreline sedimentation.

A few fish passage barriers apart from those caused by sill effects are present in the Lake Chelan Watershed. Railroad, Safety Harbor, and Prince Creeks all have high water velocity barriers (Duke Engineering Services, Inc. 2000a), the first due to high runoff and the latter two to the stream gradient. Although not caused by the dam, the gradient barriers may be influenced by fluctuating lake elevations. Five streams investigated in the same study showed gradient barriers in the dam drawdown zone. These are formed by wind-driven waves transporting sediment from alluvial fans to deeper water. The five such barriers observed in the Lake Chelan Watershed are indirectly influenced by dam operations, as wind-driven waves create a gradient at the lake elevation at the time they are generated.

Table 1. Major impacts and affected ecological functions in the Lake Chelan Watershed.

Impact Source	Impact Action(s)	Function(s) Affected
Fire suppression	Loss of riparian vegetation, flashy stream flows, erosion and sedimentation	Water quality, hydrology, habitat
Land conversion	Loss of shrub-scrub, wetland, and riparian; pesticide and fertilizer use; irrigation; invasive species propagation	Water quality, habitat
Dam operations	Raised/fluctuating lake levels, entrainment, fish passage barriers	Hydrology, habitat, lake ecology
Docks and piers	Shading, structure in water	Habitat
Bulkheads and armoring	Loss of lakeshore vegetation, wetland loss, wave action alteration, erosion, alteration in recruitment of woody debris and sand/gravel	Hydrology, habitat
Non-fish-passable culverts	Fish passage barriers	Habitat, lake and tributary ecology
Other terrestrial development	Loss of native vegetation, ornamental species propagation, septic systems	Water quality, habitat
Agriculture and grazing	Loss of scrub-shrub, wetland, and riparian; pesticide and fertilizer use; sedimentation and erosion	Water quality, habitat
Fish introduction	Disruption of the food web, complex habitat interactions	Lake and tributary ecology

3.4 Fisheries and Species Interactions

The fish community in Lake Chelan and its tributaries is an assemblage of native and non-native species (Table 2). The lake has a long and complex history regarding fish populations. The following species accounts for major fish species in the watershed and are taken from the Lower Lake Chelan ILF Prospectus (The Watershed Company 2010). Main impacts and interactions among species are summarized in Table 3.

3.4.1 Westslope Cutthroat Trout

Historic and recent surveys and research summaries of native westslope cutthroat trout indicate a decline in cutthroat numbers in the lake from historic healthy levels in the late 1800s and early 1900s (Brown 1984, Duke Engineering 2000, Chelan County PUD 2007). Recent efforts have resulted in the capture of very low numbers of westslope cutthroat trout in both Lake Chelan and its tributaries (Chelan County PUD 2007; Hillman and Giorgi 2000). Resident cutthroat were observed in four of eight electrofished streams in 1999 and 2000. A 1999 survey resulted in the capture of just three fish, however (Duke Engineering Services 2001). Snorkeling surveys in 1999 and 2000 revealed adult cutthroat in Prince Creek in 1999 and resident fish in all nine streams surveyed in 2000. In addition, adfluvial trout were observed in First, Grade, Twenty-Five Mile, Safety Harbor, Prince, and Railroad Creeks. Relicensing documents completed by the Chelan County PUD (2001) support the assertion that cutthroat presently use the lake in very small numbers.

Lake Chelan cutthroat typically spawn from mid-April through June (Berg 2004). Findings of a 2000 study (Duke Engineering Service 2001) indicated late spawning and subsequent late emergence of smaller-than-average fry, likely compromising survival. Adfluvial trout gained access to Grade, Twenty-Five Mile, and Railroad Creeks only after high flows had abated, and Grade and Safety Harbor Creeks likely presented gradient barriers to upstream passage. High discharge appeared to present a velocity barrier in Twenty-Five Mile and Railroad Creeks. Estimated spawning time of trout in Railroad Creek suggests that a passage barrier did not exist until flows lessened or adequate pool elevation was achieved.

A 2009 study revealed no evidence of cutthroat trout spawning in Mitchell, Gold, Grade, or Safety Harbor Creeks in that year (Johnson and Archibald 2009). Later snorkel surveys found three hatchery cutthroat trout in Gold Creek and four resident cutthroats in Safety Harbor Creek, as well as possible cutthroat-rainbow trout hybrids. No adfluvial trout were observed in any of the four creeks. Although low stream flow potentially created a barrier to upstream migration in Mitchell Creek, and gradient and high-flow barriers existed at the mouths of Gold and Grade Creeks during the spawning survey time period, Safety Harbor Creek did not appear to present any passage barriers to upstream migration in 2009; adfluvial cutthroat trout could have potentially migrated upstream during the spawning period.

Hatchery operations that removed fish from the Stehekin River without replacement, coupled with non-native species introduction, resulted in the collapse of the Stehekin cutthroat population. High harvest rates, logging, mining contaminants, lake level fluctuations, and urbanization all probably contributed to the species' decline in the watershed overall.

Reintroduction efforts have been implemented in several tributaries, including First, Rainbow, Railroad, Pyramid, Safety Harbor, Mitchell, Fish, and Twenty-Five Mile Creeks and the Stehekin River and Domke Lake. Hatchery-reared fish release continues in Lake Chelan nearly annually, in an effort by WDFW to replace the rainbow trout population with native cutthroat.

3.4.2 Chinook Salmon

Landlocked Chinook salmon were introduced to Lake Chelan in 1974 and supported a strong recreational fishery from the late 1980s through the early 1990s (Chelan County PUD 2007). Since then, populations have exhibited declines. Based on current catch per unit effort statistics, Chinook contribute little to the Lake Chelan fishery, although creel survey numbers were higher when only those fishermen who targeted the species were considered (Duke Engineering Services 2000). Anecdotal evidence and unpublished records also indicate a declining harvest since 1996 (WDFW 2002). Reasons for losses have been investigated and may include low survival of stocked fish, low reproductive rates, rearing condition changes in stocked fish, emigration of smolts, over-harvest, and improved angling techniques (WDFW 2002, Chelan County PUD 2007).

Flood waters in the Stehekin River in 1995 greatly impacted Chinook reproductive success and appear to have been the beginning of an accelerated decline. WDFW hatchery supplementation efforts have been unsuccessful in recent years as well, and lake trout stocking took place from 1980 to 1983, and again from 1990 to 2000. Competition between the trout and Chinook reduced the number of Chinook surviving to adult size (WDFW 2002).

Current management recommendations for the species include managing Chinook with stocked triploid fish at levels high enough to support a sport fishery, but not so high as to preclude cutthroat trout success. This recommendation would involve balancing the Kokanee population as well. Alternatively, efforts to promote a self-sustaining naturally reproducing population could include stocking with diploid fish and eggs in tributaries and limiting harvest so that more landlocked fish spawn.

3.4.3 Kokanee

Kokanee were introduced in Lake Chelan in the early 1900s and have become the most popular sport fish in the lake (Duke Engineering Services 2000, WDFW 2002). Populations declined with the introduction of mysis shrimp (*Mysis relicta*) (Brown 1984), but much higher levels have returned since 1990 (Berg 2004).

The majority of spawning Kokanee are in First, Twenty-Five Mile, and Safety Harbor Creeks, and Company and Blackberry Creeks, tributaries of the Stehekin River, with up to 95 percent of spawning occurring in the Stehekin tributaries exclusively since 1990 (Berg 2004). A noted decline in spawners in Company Creek from 1976 to 1981 may have been due to competition from newly introduced mysis shrimp or predation by Chinook, introduced in 1974. A summary of surveys from 1981 to 2008 shows a steady increase in escarpment until 2005 in the five primary spawning creeks (Keesee et al. 2009). Chelan County PUD spawner counts from 1981 through 1999 revealed high year-to-year variability in peak numbers, but no trends, and highest returns in 1999. Kokanee appeared to be fully utilizing the available substrate; because the preferred size spawning gravel is scarce, that may be the limiting factor for spawning in the tributaries studied (Duke Engineering Services 2000). A great decrease in 2006 and 2007 was likely the result of a 2003 flood event in the Stehekin Valley which scoured redds (Keesee et al. 2009). Recent reports indicate increased numbers. Population expansion in the Stehekin River is of concern to agencies because of possible impacts on native fish and invertebrates, changes in populations of species that eat or scavenge kokanee, increases in human-bear interations, and alteration of nutrient and pesticide levels (Chelan County PUD 2007), all of which may result from increased Kokanee numbers in the river.

PUD is required by permitting obligations to fund annual salmonid rearing, presently for Kokanee. Stocking by WDFW continues, and despite estimates of approximately 40 percent of the fishery reportedly being hatchery fish, researchers (Duke Engineering Services 2000) had low confidence in their ability to determine hatchery origin from scale analysis.

3.4.4 Bull Trout

Bull trout have not been verified in Lake Chelan since the 1950s and are most likely extirpated in the lake (Brown 1984, Chelan County PUD 2001, (Berg 2004). The reasons for extirpation are not certain. Postulations include the floods of 1948-1949 wiping out the species' spawning grounds, a pathogen, and fishing pressure reducing numbers to the point where the species could not recover (Brown 1984).

Several stakeholders, including the USFWS, have proposed investigating the possibility of restoring bull trout to the Chelan Watershed. A survey for remnant populations and suitable habitat in the basin would precede any reintroduction effort. Limiting factors would need to be identified and eradicated. Concerns about the feasibility of the reintroduction of bull trout focus on non-native species populations in the lake, remaining pathogens, and availability of donor stock, among other considerations (Chelan County PUD 2007).

3.4.5 Lake Trout

Lake trout were introduced to Lake Chelan in the early 1980s and were the focus of a sustained stocking program by WDFW from 1990 to 2000 (WDFW 2002). Lake trout have fared well in Lake Chelan and appear to be reproducing naturally based on fry sightings during snorkel surveys. Additionally, sport catch data indicate a rapidly increasing population and, as a result, WDFW removed sport harvest restrictions in 2003. Lake trout became the most popular sport fishery as the landlocked Chinook fishery declined. Several fish over 30 lbs have been caught in the past ten years, including the Washington State record of 35 lbs 7 oz taken on December 31, 2001. Lake trout appear to present negative species interactions as an introduced top predator, and information from other lakes indicates that lake trout can have a significant negative impact on native fisheries. Management and regulatory agencies who participate on the Lake Chelan Fishery Forum recommend discontinuing lake trout stocking programs, evaluating the feasibility of eradication methods, developing a monitoring program to evaluate management actions, and studying natural reproduction of lake trout in the lake and its tributaries.

Concentration of DDT in lake trout adipose tissue has been used as an indicator of DDT in the watershed. Fish tissue concentrations have exceeded health standards and resulted in the inclusion of DDT on the 303(d) list for water quality impairment in Lake Chelan. Lake trout consumption health advisories have been issued by the Chelan-Douglas Health District, which recommended that at-risk populations limit their lake trout intake to appropriate levels.

3.4.6 Rainbow Trout

Rainbow trout have been stocked in Lake Chelan since the early 1900s and have been a supplemental recreational fishery to Kokanee as Kokanee production has lagged. Rainbow trout have been shown in other systems to outcompete and hybridize with westslope cutthroat trout, thereby adversely affecting efforts to establish viable native populations of cutthroat trout. Fisheries managers, local interests and regulatory agencies appear to agree that management actions should focus on the eventual elimination of rainbow trout from Lake Chelan by shifting stocking activities to cutthroat trout and eliminating the stocking of rainbow trout in the basin, including the high lakes and tributaries. Since 2005 there has been no stocking of rainbow trout in the basin, with the exception of non-reproducing triploid rainbow trout to support the recreational fishery.

3.4.7 Smallmouth Bass

As is the case with many of the "minor" species of fish in Lake Chelan, smallmouth bass were introduced illegally, probably sometime around 1990. There is currently an active, but limited, fishery, and the population appears to be increasing, although the distribution of the species is somewhat unknown. Risks from an increasing population on other species far outweigh the rewards, and management objectives emphasize control and removal of the population, particularly in the Lucerne sub-basin. The Lake Chelan Fishery Forum does not recommend any enhancement measures for smallmouth bass.

3.4.8 Eastern Brook Trout

Eastern brook trout have become established in Twenty-Five Mile Creek and the Stehekin River, and during the 1980s and 1990s WDFW stocked eastern brook trout in Twenty-Five Mile Creek and the Manson Lakes. The presence of eastern brook trout adversely affects native fisheries through competition and disease, and is a significant impediment to bull trout and cutthroat trout recovery efforts. There is agreement among the management agencies that the species should be eradicated.

3.4.9 Other Species

Other native fish species include pygmy whitefish (*Prosopium coulteri*), mountain whitefish, threespine stickleback (*Gasterosteus aculeatus*), peamouth, chiselmouth (*Acrocheilus alutaceus*), burbot, prickly sculpin (*Cottus asper*), and northern pikeminnow. Pygmy whitefish is listed as a Washington State Species of Concern. The effects of non-native fish stocking on these native species is unclear.

Additional non-native species observed in Lake Chelan and the Chelan River are largemouth bass (*Micropterus salmoides*), pumpkinseed (*Letomis gibbosus*) and bluegill (*L. macrochirus*). Non-fish introductions in the lake include Eurasian milfoil, zebra mussel and Quagga mussel.

Table 2. Fish species in the Lake Chelan Watershed.

Species	Scientific name	Native	Non-native
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	X	
Bull trout	*Salvelinus confluentus*	X	
Mountain whitefish	*Prosopium williamsoni*	X	
Pygmy whitefish	*P. couterii*	X	
Burbot	*Lota lota*	X	
Largescale sucker	*Catostomus macrocheilus*	X	
Longnose sucker	*C. catostomus*	X	
Bridgelip sucker	*C. columbianus*	X	

Species	Scientific name	Native	Non-native
Northern pikeminnow	*Ptychocheilus oregonensis*	X	
Peamouth	*Mylocheilus caurinus*	X	
Threespine stickleback	*Gasterosteus aculeatus*	X	
Chiselmouth	*Acrocheilus alutaceus*	X	
Mottled sculpin	*Cottus bairdi*	X	
Slimy skulpin	*C. cognatus*	X	
Prickley sculpin	*C. asper*	X	
Redside shiner	*Richardsonius balteatus*	X	
Rainbow trout	*O. mykiss*		X
Kokanee	*O. nerka*		X
Landlocked Chinook salmon	*O. tshawytscha*		X
Lake trout	*S. namaycush*		X
Smallmouth bass	*Micropterus dolomieu*		X
Largemouth bass	*M. salmoides*		X
Eastern brook trout	*S. fontinalis*		X
Pumpkinseed	*Lepomis gibbosus*		X
Bluegill	*L. macrochirus*		X

Table 3. Major fish species interactions, impacts and production in the Lake Chelan Watershed.

Species	Impacts and Interactions	Function/Use	Reproduction/Support
Bull trout	Decline due to over-harvest, interbreeding, disease, loss of spawning habitat; reintroduction hindered by competition from Kokanee and trout	Historic occurrence, threatened species	Not observed in Lake Chelan or tributaries since early 1950s
Chinook salmon	Forage competition from mysids and lake trout, hatchery conditions, flooding, over-harvest, improved angling methods	Strongly supported recreational fishery until early 1990s, community desire to rebuild fishery	Reproduces naturally in low numbers, stocked, declining population
Kokanee	Forage competition from mysids, predation by Chinook, flooding, interbreeding	Strongly supported recreational fishery	Reproduces naturally, expanding population in Stehekin River, stocked previously, 2007 spawners found sufficient to support population
Western cutthroat trout	Gradient and velocity barriers, competition from non-natives, over-harvest, mining contaminants, logging impacts, hatchery operations, interbreeding	Strongly supported recreational fishery	Reproduces naturally in tributaries, stocked with hatchery fish, hybridizes with rainbow trout
Lake trout	Compete with and prey on native fish, exceed DDT health standards in adipose	Popular trophy fish	Reproduce naturally in Lake Chelan, stocked previously

Rainbow trout	Outcompete and hybridize with native cutthroat trout	Triploids supplement cutthroat fishery	Stocked since early 1990s, hybridize with cutthroat trout, no reproductive fish stocked since 2005, triploids stocked
Smallmouth bass	Danger of competition with or predation of native fish	Recreational fishery	Introduced illegally in 1990, reproducing in and presently limited to Wapato sub-basin
Eastern brook trout	Compete with native fish; spread disease	Recreational fishery	Established in Stehekin River and Twenty-five Mile Creek from historic stocking

In addition to species statuses and interactions, present and historic habitat issues and conditions in the Lake Chelan Watershed are described in the ILF Framework. Anthropogenic impacts on each habitat type affect aquatic habitat in Lake Chelan and its tributaries by altering water quality and/or quantity and availability and quality of habitat. Impacts to habitats present in the watershed are summarized in Table 4.

Table 4. Wildlife habitat types occurring in the Lake Chelan Watershed and main environmental threats (from Johnson and O'Neil 2001).

Habitat Type	Dominant Species	Main Impacts/Threats
Montane mixed conifer forest	*Tsuga mertensiana, Abies lasiocarpa, Picea engelmannii*	Clear-cutting and plantations, road-building impact structure and composition, affect seral stage distribution, and promote fragmentation
Eastside mixed conifer forest	*Pseudotsuga menziesii, Pinus ponderosa. Grandis, Thuja plicata, T. heterophylla*	Timber harvest and fire suppression leave shade-tolerant, fire-resistant trees, as well as densely stocked stands lacking snags; late seral forest nearly absent, mid-seral forest artificially abundant
Lodgepole pine forest and woodlands	*P. contorts* vars. *latifolia* and *murrayana*	Fire suppression leaves stands to develop multiple layers; lack of natural regeneration creates "pumice deserts"
Ponderosa pine forest and woodlands	*P. ponderosa, P. menziesii*	Fire suppression has resulted in heavy fuel loads and stand-replacing fires; forests are increasingly closed-canopy mad multi-layered; grazing removes grass cover and favors shrub, oak and conifer growth; most management regimes lead to smaller trees in denser stands

Habitat Type	Dominant Species	Main Impacts/Threats
Upland aspen forest	*Populus tremuloides*	Livestock browsing and fire suppression have greatly reduced aspen habitat since 1900
Subalpine parkland	*Pinus albicaulis, Laryx lyallii*	Fire suppression has altered structure and function and resulted in blister rust; logging and other disturbance have a great impact because of naturally slow regeneration rates
Alpine grassland and shrublands	*Festuca idahoensis, F. brachyphylla, F. viridula, F. saximontana, Danthonia intermedia*	Trampling and other recreational impacts can result in bare ground not suitable for vascular plant growth; exotic ungulates cause degradation and erosion
Eastside grasslands	*Pseudoroegneria spicata, F. idahoensis, F. campestris*	Livestock have altered vegetative makeup; non-native grasses now dominate in riparian bottomlands
Shrub-steppe	*Artemisia tridentate* ssp. *tridentate, A.t.* ssp. *Wyomingensis, A.t.* ssp. *Vaseyana, Purshia tridentate, A. cana, A. tripartita*	Conversion to orchard, pasture, other development has reduced this habitat; grazing has altered species composition and promoted conversion to invasive species
Agriculture, pasture and mixed environs	Orchard, vineyard, pasture	May receive fertilizer and pesticide inputs; crops, grazing, and other management and uses prevent reversion to native vegetation; grazing may increase exotic species
Urban and mixed environs	Remnant native vegetation, ornamentals, invasive species	Degraded conditions in these areas are most often irreversible and include many types of anthropogenic impacts
Open water – lakes, rivers and streams	May include aquatic bed	Agricultural runoff, shoreline hardening, overwater structures, dams, passage barriers, flood control measures, forestry practices, and numerous sources of development impact water quality, quantity, and habitat characteristics
Herbaceous wetlands	*Typha latifolia, Scirpus* spp.*, Carex* spp.*, Juncus* spp. and many others	Channeling, filling, and diverting hydrology for agriculture and development have reduced and degraded wetlands
Montane coniferous wetlands	*P. engelmannii, A. lasiocarpa, P. contorta, T. heterophylla, P. menziesii, A. grandis*	Roads and clearcutting increase flooding and debris flows; logging reduces woody debris and canopy structural complexity

Habitat Type	Dominant Species	Main Impacts/Threats
Eastside riparian wetlands	*P. balsamifera* ssp. *trichocarpa, P. tremuloides, Alnus rhombifolia, Salix amygdaloides, Betula papyrifera, B. occidentalis, S. lucida* ssp. *caudate, S. bebbiana, S. boothii, S. exigua*	Dams, roads, logging, and excessive grazing all impact habitat, hydrology, water quality, and vegetative structure and composition.

4. Existing Restoration Goals and Objectives

4.1 Watershed-specific

A number of studies and reports have defined restoration goals for the Lake Chelan Watershed. These are summarized in the following sections.

4.1.1 WRIA 47 Watershed Planning Phase II

Goals of the Long-Term Monitoring Plan for Lake Chelan for water quality in WRIA 47 habitat restoration by focusing on evaluating water quality. These goals are listed in the plan as follows:

1. Develop a monitoring design supported by water quality models that can be used to evaluate trends in water quality parameters.

2. Evaluate concerns about potential concerns about potential future changes in water clarity and lake eutrophication.

3. Develop a monitoring approach for constituents that have completed TMDLs to allow a determination of the effectiveness of post-TMDL remedies (phosphorus, DDT analogs, PCBs).

4. Develop a monitoring design for 303(d)-listed constituents in Lake Chelan that have not yet been addressed by completing a TMDL.

5. Recommend data quality objectives and analytical methods to ensure greater consistency and comparability of data in the future.

6. Develop a monitoring program that can be used to evaluate best managements practices (BMPs) that may be implemented to address water quality concerns.

4.1.2 WRIA 47 Final Draft Planning Unit Charter

The WRIA 47 Planning Unit has the goal "to implement a management plan for water use and protection that sustains the environmental, educational, economic and recreational values associated with a healthy lakeside community and watershed." The following objectives were outlined in the *WRIA 47 Final Draft Planning Unit Charter* (RH2 Engineering and Geometrix Consulting 2007).

1. Assess water supply, use and projected needs.
2. Develop and implement a comprehensive, long-term monitoring program of key parameters that will ensure water quality sustainability throughout the Lake Chelan Watershed.
3. Address waterbodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.
4. Inform and educate local communities and visiting populations about water quality protection.
5. Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources.

4.1.2 Lake Chelan Fishery Plan (LCFP)

The Lake Chelan Hydroelectric Project relicensing article (Chelan County PUD 2007) presents three fishery management goals, and several objectives toward meeting the goals:

Goals:

1. Provide guidance for the management of the fishery resources in Lake Chelan.
2. Protect native fish populations while maintaining a healthy recreational sport fishery in Lake Chelan.
3. Develop a monitoring and evaluation program to assess the efficacy of management action.

Objectives:

1. Emphasize restoration/enhancement of native species, where feasible.
2. Support the recreational sport fishery.

3. Manage the lake elevation to enhance tributary production and recreation.

4. Determine the compatibility of management actions with potential future bull trout reintroduction.

5. Develop a monitoring and evaluation program that provides flexibility for future changes in both implementation and the monitoring and evaluation program.

6. Monitor and address entrainment of fish from Lake Chelan into the Project intake.

4.1.3 Lake Chelan Sub-basin Plan

The LCSP (Berg 2004) established the goal to "restore conditions to a more natural state" by employing "ecosystem-based perspectives that consider multiple species, their life histories, and their inter-relationships." The LCSP includes a detailed inventory, and concludes with a management plan that lists a number of habitat or biological objectives for key species and key habitats in the basin.

Many of the objectives are to conduct additional species/habitat assessments, "identify and provide biological and social conservation measures to sustain focal species populations and habitats," and in a number of instances to "[m]aintain and/or enhance habitat function (i.e., focal habitat attributes) by improving silvicultural practices, fire management, weed control, livestock grazing practices, and road management…" Because the intention of this portion of the LCSP is to identify and direct aquatic restoration and management approaches, only those goals that directly address aquatic habitat restoration and fish management are summarized here without stated deadlines.

1. Provide sufficient quality and quantity of riparian wetlands to support focal species identified in the sub-basin plan, including the fish species addressed in this list.

2. Remove tributary barriers and /or alter lake level management to make historic westslope cutthroat trout spawning grounds available earlier.

3. Cease stocking of non-native species that negatively impact cutthroat trout.

4. Remove or decrease numbers of key exogenous species.

5. Reduce naturally-produced cutthroat trout harvest impacts.

6. Determine if bull trout exist in the sub-basin.

7. If bull trout are found in the sub-basin, work toward achieving self-sustaining non-migratory populations.

8. Reduce abundance of exogenous fish that may hinder bull trout reintroduction, if it is to occur.

9. Preserve historic bull trout habitat.

10. Reduce negative impacts of mysids on kokanee.

11. Increase kokanee juvenile survival and adult abundance.

12. Achieve self-sustaining kokanee populations.

4.2 Other Plans and Programs with Restoration Goals

Several other plans and policies include as goals preservation and/or enhancement of aquatic habitat or related elements. These more general goals are addressed in the following sections.

4.2.1 Chelan County Shoreline Master Program Update Draft Shoreline Restoration Plan

The Draft Shoreline Restoration Plan (The Watershed Company and ICF 2010) lists goals from plans, programs and policies for all of Chelan County. Those applicable to WRIA 47 were taken from the Lake Chelan Sub-basin Plan and are listed in Section 4.1.2.

4.1.4 Chelan County Comprehensive Plan

The 2005 *Chelan County Comprehensive Plan* was developed in accordance with Section 36.70A.070 of the Growth Management Act to address land uses. The Plan covers the unincorporated areas outside of the city urban growth areas. Seven study areas were identified within the county-wide plan, encompassing the following study areas: Chelan-Manson, Entiat Valley, Malaga-Stemilt-Squilchuck, Lower Wenatchee River Valley, Upper Wenatchee River Valley, Plain-Lake Wenatchee, and Stehekin (Chelan County 2005).

A Rural Coordinating Committee, made of 12 members appointed by the Board of Commissioners to coordinate the Rural Element of the Plan, together with the Planning Commission, went through a process where they identified goals and policies applicable to specific study areas, and goals and policies applicable county-wide. In particular, the Plan expresses a goal of identifying and protecting critical areas and mitigation adverse impacts that may result from reasonable use. Policies include encouraging the enhancement and restoration of fish and wildlife habitat.

4.2.1 Chelan County Critical Areas Regulations

Chelan County's critical areas regulations were recently updated (2007), and are considered to be consistent with Growth Management Act "best available science" standards. Many of the issues and concerns that guided the development of the critical area regulations were discussed and addressed in the comprehensive planning process. The land use element of the comprehensive plan is required to review; where applicable, drainage, flooding, and storm water run-off and to provide guidance for corrective actions to mitigate or cleanse those discharges that pollute waters of the state. Included in the goals set by Chelan County are three that pertain directly or indirectly to aquatic habitat, numbered below as they are in the plan:

> <u>Goal 1</u>: Protect water quality.
>
> <u>Goal 3</u>: Ensure that development minimizes impacts upon significant natural, historic, and cultural features and to preserve their integrity.
>
> <u>Goal 4:</u> Identify and protect critical areas and provide for reasonable use of private property while mitigating adverse environmental impacts.

4.2.2 City of Chelan Plans and Regulations

The *City of Chelan Comprehensive Land Use Plan* (2007) follows the recommendation of the Growth Management Act (GMA) by adopting goals and policies to "protect critical areas," that include wetlands, geologically hazardous areas, aquifer recharge areas, fish and wildlife habitat conservation areas and frequently flooded areas. The City of Chelan established critical area goals and policies that were adopted in 1998. Goals include the general "protect water quality."

The City of Chelan's environmental regulations are found in the *Chelan Municipal Code*, Chapter 14.10, and are currently being updated. These regulations "establish special standards for the use and development of lands based on the existence of natural conditions and features including geologically hazardous areas, critical aquifer recharge areas, frequently flooded areas, fish and wildlife conservation areas and wetlands." The standards and procedures established in Chapter 14 are intended to protect environmentally sensitive areas while accommodating the rights of property owners to the use of their property in a reasonable manner. The Code includes a goal of protecting unique and fragile environmental elements, including wetlands.

4.2.3 City of Chelan Parks and Recreation Comprehensive Plan

The *City of Chelan Comprehensive Land Use Plan* (2007) is intended to implement comprehensive land use planning at the local level, maintain local decision making power, and promote desired changes. An element to the Plan is the *Parks and Recreation Comprehensive Plan 2008-14* (2007). The element includes a commitment to managing and expanding the community's resources, including conservation of natural resources and support for the City's economic vitality (City of Chelan Parks and Recreation Department 2007). The Department established goals and objectives, including priority actions. The environment protection goal is:

PRG 6.0: Protect and preserve as open space areas that: are ecologically significant sensitive areas; provide significant opportunities for restoration buffers between uses and link open space; provide trails and/or wildlife corridors; or enhance fish habitat.

4.2.4 City of Chelan Strategic Plan 2008-2009

The 2008 City of Chelan's *Strategic Plan 2008-2009* vision statement includes relevant information "to preserve and improve the quality of life for the citizens of the community and for visitors to the area by achieving/creating….the preservation of natural resources and water quality….and a commitment to maintaining existing city resources/facilities." The relevant strategic goal and objective are as follows:

> Goal: To improve the quality of life and environment in the Lake Chelan area;
>
> Objective: Complete Don Morse Park Master Plan and initiate phased development with a focus on shoreline stabilization, beach enhancement, and reassessment of size of marina.

5. Existing Recommendations and Strategies

Various interested agencies and entities in the Lake Chelan Watershed have completed studies or documents outlining aquatic habitat recommendations, and often have proposed strategies for implementing recommendations. The most detailed and specific of these are species-based (see Sections 5.2 and 5.3); species-based summaries are presented in Table 5.

5.1 WRIA 47 Final Draft Planning Unit Charter

The Planning Unit promotes long-term strategies toward the implementation of their water resource goals. These are copied from the Charter below:

1. Fully engage all stockholders through an open accessible and collaborative effort.
2. Develop and implement a comprehensive, long-term monitoring program of key parameters that will ensure water quality sustainability throughout the Lake Chelan Watershed.
3. Address water bodies with constituents on the State 303(d) list and other parameters of potential concern that threaten lake water quality.
4. Inform and educate local communities and visiting populations about water quality protection.
5. Develop a Water Quality Improvement Plan and Water Quality Management Plan to understand, restore and protect water resources.

5.2 Lake Chelan Fishery Plan (FERC Project No. 637)

The LCFP was developed in consultation with the National Park Service (NPS), US Forest Service (USFS), US Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), Washington Department of Fish and Wildlife (WDFW), Confederated Tribes of the Colville Reservation, Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, the City of Chelan, and the Lake Chelan Sportsman's Association, which formed the Lake Chelan Fishery Forum (LCFF). The LCFF proposed a number of recommended actions to meet the management objectives of the LCFP (see Section 3.2.1). Recommendations are almost entirely species-based and have in some cases been implemented or otherwise addressed, although further reporting was generally not required by FERC (see Table 5). The recommended strategies are derived from issues raised by stakeholders during the relicensing process.

5.2.1 Westslope Cutthroat Trout

Recommendations for enhancing cutthroat trout populations are as follows:

1. Replace the 2007 100,000 rainbow trout allotment with increasing proportions of Twin Lakes cutthroat trout over a four-year period, after which only cutthroat trout are stocked. Suggested strategies for stocking Twin Lakes cutthroat include stocking catchable sizes, planting eyed eggs in tributaries, maintaining a recreational trout fishery with Twin Lakes

cutthroat, prioritize Lake Chelan fish management needs in allocation of Twin Lakes eyed eggs, and locate other sources of Twin Lakes cutthroat or other cutthroat stocks for use in other Washington waters.

6. Immediately (as of 2007) eliminate rainbow trout stocking in high lakes and tributaries in the Lake Chelan Watershed.
7. Remove barriers and manage lake water levels to improve tributary access for spawning, incubation and rearing.
8. Implement monitoring and evaluation to assess efficacy of management actions.
9. Maintain fishing restrictions at tributary mouths to protect spring spawning salmonids until the cutthroat trout population recovers.
10. Stock cutthroat trout after completion of spill to enable stocked fish to survive the winter in the lake and return to tributaries to spawn, thereby contributing to natural reproduction.

5.2.2 Rainbow Trout

Recommendations for phasing out rainbow trout are:

1. Phase out rainbow trout stocking over a four-year period as cutthroat stocking increases (see Section 4.1.1 (1)); monitor and evaluate the effort as it proceeds.
2. Immediately (as of 2007) eliminate rainbow trout stocking in high lakes and tributaries in the Lake Chelan Watershed and in the Lucerne Basin of Lake Chelan.
3. Explore the feasibility of stocking triploid rainbow trout for recreational angling if the cutthroat trout recreational fishery is insufficient.

5.2.3 Kokanee

Although they are non-native, kokanee are the most popular recreational fish in Lake Chelan and therefore subject to Objective 2 (Section 3.1.2) of the Lake Chelan Fishery Plan. Recommendations for achieving goals for kokanee are:

1. Develop an interim stocking plan for all species, but emphasizing the issues regarding kokanee stocking, to be kept in place until monitoring and evaluation can be implemented to provide better information for making long-term management decisions.

2. Develop population size goals that are compatible with native species recovery and protection goals, and with National Park Service goals for the Stehekin River.

3. Monitor populations to provide a basis for the following actions:

    a. Stock when populations decline below established objectives.

    b. Maintain a recreational kokanee fishery.

    c. Develop a monitoring and evaluation program to assess the efficacy of management actions, with particular attention to the effect of stocking on kokanee numbers in the lake and the spawning population in the Stehekin sub-basin.

4. Discontinue stocking after spill has stopped (September or October).

5.2.4 Landlocked Chinook Salmon

This species was a strong recreational and commercial (guided) fish in the 1980s and 1990s; the Chelan community has shown a strong desire to restore the annual Chinook Derby, which was a significant economic event in the past. However, the NPS and FWS have raised concerns about stocking in Lake Chelan despite continuing declines in native fish populations. Recommendations by the LCFF include attempts to address these divergent issues regarding the species.

1. The suggested Interim Stocking Plan should pay special attention to the issue of stocking landlocked Chinook.

2. Investigate predation aspects of landlocked Chinook salmon; this work should include looking at the feasibility of stocking triploid Chinook, setting interim harvest restrictions to protect populations, and supporting a recreational fishery.

3. Evaluate the impacts of Chinook on native fish species in Lake Chelan and consider management actions that would limit impacts; support a recreational fishery if impacts are found to be minimal.

4. Discontinue stocking lake trout.

    a. Stop juvenile stocking.

    b. Reduce the adult population.

    c. Investigate the presence and absence of natural lake trout reproduction in Lake Chelan and tributaries.

5. Implement monitoring and evaluation to assess efficacy of management actions.

5.2.5 Bull Trout

There have been no documented occurrences of bull trout in Lake Chelan or its tributaries since the early 1950s. Relicensing stakeholders, particularly FWS, expressed a desire to determine the feasibility of restoring the species to the Lake Chelan Watershed. If such an effort is found to be feasible, the goal of the State and federal agencies would be self-sustaining populations in the historical habitat in the Stehekin River and tributaries of the Stehekin River and Lake Chelan. Associated recommendations by the LCFF as are follows:

1. Conduct a feasibility study of reintroducing fluvial and adfluvial bull trout.
2. Prioritize maintaining recreational fishing opportunities for other species.
3. Develop a monitoring and evaluation program to assess efficacy of management actions.
4. Discontinue brook trout and lake trout stocking.
5. Reduce adult brook and lake trout populations.

5.2.6 Lake Trout

1. Discontinue lake trout stocking.
2. Assess population size, recruitment, distribution, and spawning areas and explore potential eradication methods.
3. Develop a monitoring and evaluation program to assess efficacy of management actions.
4. Look at presence/absence of naturally reproducing fish in Lake Chelan and its tributaries.

5.2.7 Burbot

1. Develop a monitoring and evaluation program to assess efficacy of management actions.
2. Monitor abundance, survival, and recruitment trends; evaluate the effects of fishing regulations and disease screening.

5.2.8 Smallmouth Bass

1. Develop a monitoring and evaluation program to assess efficacy of management actions.

2. No enhancement measures directed at this species are recommended (as of 2007).

3. Monitor water temperature and smallmouth bass distribution/abundance in the Lucerne sub-basin and Stehekin Flats.

4. Implement removal actions if smallmouth bass are found in the Lucerne sub-basin.

5.2.9 Eastern Brook Trout

1. Eradicate eastern brook trout from Twenty-five Mile Creek and the Stekehin River using all feasible means.

2. Adopt fishing regulations to encourage harvest of eastern brook trout, provided bull trout restoration has not been implemented and there is no chance of incidental bull trout harvest.

5.2.10 Other Native Fish Species

1. Develop a monitoring and evaluation program to assess efficacy of management actions.

5.2.11 Other Non-native Fish Species

1. No further introduction of non-native species.

2. No introductions of anadromous fish to Lake Chelan.

5.2.12 Invasive Aquatic Plant Species

As part of the Lake Chelan Fishery Plan, the Chelan PUD agreed to provide signage at PUD-operated boat launches to inform the public about invasive species and prevention of transmitting them between water bodies. As well, the Chelan PUD agreed to report to Ecology and the LCFF any invasive species observed during project monitoring and inspection.

5.3 Lake Chelan Sub-basin Plan (LCSP)

The LCSP generally calls for promoting self-sustaining kokanee and westslope cutthroat trout through harvest reduction and eliminating non-native species, and for reintroducing bull trout. The following strategies are aimed at achieving the aquatic biological goals of the Subbasin Plan. As in the LCFP (Section 5.2), strategies for reaching aquatic goals are species-based.

5.3.1 Westslope Cutthroat Trout

In order to reach the goals of improving Lake Chelan Watershed conditions for cutthroat trout, the Sub-basin plan recommends the following strategies.

1. Remove tributaries barriers mechanically.
2. Complete a fish stocking plan for all species that may negatively impact Cutthroat trout.
3. Increase Chinook and lake trout harvest.
4. Remove harvest limits on brook and rainbow trout.
5. Determine cutthroat trout early life history requirements.
6. Investigate interactions, if any, between kokanee spawning and cutthroat fry emergence.
7. Delay fishing season opening near tributary mouths in Lake Chelan until after cutthroat spawning season.

5.3.2 Bull Trout

Overall goals pertaining to bull trout are to determine their existence status in the Lake Chelan Watershed, promote a self-sustaining population if they are found to exist, and to protect historic habitat. Recommended strategies are:

1. Investigate areas that may support reserves of non-migratory bull trout.
2. If feasible, reintroduce bull trout in historic bull trout habitat; determine potential interactions with existing populations prior to any introduction.
3. Determine predator-prey interactions among species in Lake Chelan.
4. Increase harvest of Chinook salmon and lake trout.
5. Eliminate harvest limit on brook trout.
6. Preserve or restore geofluvial processes in all tributaries.

5.3.3 Kokanee Salmon

The Sub-basin Plan's goal for this species is a self-sustaining population. Strategies to achieve this are:

1. Reduce mysid abundance.
2. Increase Chinook and lake trout harvest.
3. Develop a hatchery fish planting schedule that will meet both native fish production and harvest rate goals.

5.4 Other Recommendations

The Chelan Basin Watershed Analysis (Lenz 2008), the First/Twenty-five Mile Creek Watershed Analysis (Murphy 1995), the Tributary Barrier Analysis (Duke Engineering Services 2000a), and a study of the predation impacts of lake trout and Chinook in Lake Chelan (Schoen and Beauchamp 2010) each contribute to the knowledge base of aquatic habitat and fisheries function in the lake. Unlike the work described in the preceding sections, these documents do not focus on management of the fishery, but on ecological impacts of natural and anthropogenic processes and actions in the watershed. The analyses do, however, make recommendations that pertain to the fish assemblage or individual species in Lake Chelan. They are therefore included in Table 5.

Table 5. Recommendation and strategy summary for major fish species in the Lake Chelan Watershed.

Species	Recommendation/Strategy	Source(s)*	Status	Conflict(s)
Western cutthroat trout	Replace rainbow trout stocking with cutthroat in phases	LCFF	2010 PUD plan includes Twin Lakes fry stocked in Cascade, Bear, Big, and Mill Creeks and in Lake Chelan; Eyed eggs at Four-miles Creek	Rearing conditions at Chelan hatchery are limited
	Manage water levels for spawning and rearing	LCFF	**	**
	Remove tributary barriers	LCSP, LCFF	PUD/LCFF effort includes reassessment of barriers identified in TBA; priority list to be updated; fish passage in Mitchell and Gold Creeks to begin in early 2011 (Final Design completed Aug 2009)	Watershed instability due to recent fires may thwart efforts; USFS Restoration Assistance Team recommends more time be allowed fir tributaries to carve alluvial deposits; WDFW cutthroat restoration efforts could increase natural reproduction if allowed more time
	Determine early life history requirements	LCSP	**	**
	Investigate interactions between cutthroat fry emergence and kokanee spawning	LCSP	**	**
	Delay fishery opening at tributary mouths until after spawning	LCSP	**	**
	Maintain fishing restrictions at tributary mouths	LCFF	**	**
	Implement monitoring and evaluation	LCFF	PUD creel, snorkel and spawning surveys in Lake Chelan and tributaries began in 2009; also abundance monitoring in Stehekin River and tributaries	**

	Stock after spill completion to promote winter survival and natural reproduction	LCFF	**	**
	Maintain Twin Lakes fishery	LCFF	**	**
	Allocate Twin Lakes eyed eggs to Lake Chelan	LCFF	Eyed eggs stocked in Four-mile Creek in PUD 2010 plan	**
Rainbow trout	Eliminate rainbow stocking in high lakes and tributaries	LCFF	2010 PUD stocking only in Lake Chelan and Mill Creek (triploids)	Popular fishery
	Explore feasibility of triploid rainbow stocking if cutthroat fishery is insufficient	LCFF	PUD presently stocks triploids	**
	Phase out stocking	LCFF	Only triploids stocked	Popular fishery
	Remove harvest limits	LCSP	**	**
Bull trout	Conduct reintroduction feasibility study	LCFF	**	**
	Investigate suitable habitat areas	LCSP	**	**
	If feasible, reintroduce into historic habitat	LCSP	**	**
	Determine predator-prey relationships	LCSP	**	**
	Preserve or restore geofluvial processes in tributaries	LCSP	**	**
	Maintain other recreational fisheries	LCFF	**	**
	Monitor to evaluate management actions	LCFF	**	**
Lake trout	Remove harvest limits		**	**
	Discontinue stocking	LCFF	**	Some support for fishery
	Determine whether the species reproduces naturally in the watershed	LCFF	**	**
	Explore eradication methods; locate spawning aggregations	LCFF Schoen and Beauchamps 2010	**	Some support for fishery

	Assess population parameters (population trends, distribution, and size structure)	LCFF Schoen and Beauchamps 2010	UW research includes diet, distribution	**
	Monitor to evaluate management actions	LCFF	PUD creel, snorkel and spawning surveys in Lake Chelan and tributaries began in 2009	**
	Eliminate harvest limit (for Chinook)	LCFF	**	**
Eastern brook trout	Eradicate from Twenty-five Mile Creek and the Stehekin River	LCFF	**	**
	Encourage fishing	LCFF	**	Chance of incidental bull trout harvest if bull trout are present or reintroduced
	Develop population size goals compatible with native species recovery goals and with NPS goals for the Stehekin River	LCFF	**	**
Kokanee	Monitor populations for stocking, fishing, and evaluation of management practices; assess recruitment and abundance	LCFF Schoen and Beauchamps 2010	PUD creel, snorkel and spawning surveys in Lake Chelan, the Stehekin River. and tributaries began in 2009	**
	Do not stock after spill	LCFF	**	**
	Reduce mysid abundance	LCSP	**	**
	Develop hatchery planting schedule for production and harvest goals	LCSP	**	**
Landlocked Chinook	Investigate predation aspects	LCFF	Research at UW includes diet and predation	**
	Investigate feasibility of stocking triploids	LCFF	2010 PUD triploid stocking in Mill Creek	**
	Investigate setting harvest restrictions	LCFF	**	Bull trout reintroduction recommends increased harvest

	Evaluate impacts on native fish	LCFF	Research at UW includes diet and predation	**
	Wait until kokanee population rebounds before rebuilding Chinook fishery	Schoen and Beauchamps 2010	**	**
Burbot	Monitor abundance, survival, recruitment	LCFF	PUD creel, snorkel and spawning surveys in Lake Chelan and tributaries began in 2009	**
	Evaluate effects of fishing and disease screening	LCFF	**	**
Smallmouth bass	Implement removal if discovered in Lucerne sub-basin	LCFF	**	**
	Monitor water temperature and species distribution in Lucerne sub-basin and Stehekin Flats	LCFF	**	**
	Monitor to evaluate management actions	LCFF	PUD creel, snorkel and spawning surveys in Lake Chelan and tributaries began in 2009	**
Multiple species	Implement Lake Chelan LWD and shoreline erosion management plans	CBWA	**	**
	Reduce runoff and mass wasting from roads and disturbed sites	Creeks WAP, CBWA	**	**
	Create spawning habitat in lower First and Twenty-five Mile Creeks	Creeks WAP	**	**
	Create spawning gravel monitoring plan for First and Twenty-five Mile Creeks	Creeks WAP	**	**
	Analyze riparian areas for connectivity in First and Twenty-five Mile Creeks	Creeks WAP	**	**
	Rehabilitate disturbed vegetation areas and plant areas that are inadequately shaded	Creeks WAP, CBWA	**	**

	Develop domestic water diversions that provide fish passage in First and Twenty-five Mile Creeks	Creeks WAP	**	**
	Restore riparian vegetation along Twenty-five Mile Creek in State Park	Creeks WAP	**	**
	Lower lake level in late summer/early fall to allow streams to cut through sediment deposits	TBA	**	Depends on stream energy and precipitation
	Raise lake level in winter/spring above barriers	TBA	**	Damage to lakeshore property; would raise aquatic vegetation zone
	Create tributary passage channels	TBA	**	**
	Complete a fish stocking plan	LCFF, LCSP	**	**
	No further introduction of non-native species	LCFF, CBWA	**	**
	No anadromous fish introductions	LCFF	**	**
	Monitor to evaluate management actions on all native species	LCFF	PUD began creel, spawning and snorkel surveys on cutthroat trout, rainbow trout, and Kokanee in Lake Chelan, the Stehekin River, and tributaries in 2009	**

*LCFF – Lake Chelan Fisheries Forum
LCSP – Lake Chelan Sportman's Association
CBWA – Chelan Basin Watershed Analysis (Lenz 2008)
Creeks WAP – First/Twenty-five Mile Creek Watershed Analysis (Murphy 1995)
TBA – Tributary Barrier Analysis (Duke Engineering Services 2000a)
**Unknown or not available/applicable

5.5 Draft In-lieu Fee Prospectus

The In-lieu Fee Prospectus identifies general restoration recommendations for a number of sub-basins within the lower (Wapato) Lake Chelan Watershed. These are organized by hydrologically defined sub-basin boundaries and based on resource needs at the watershed level. Table 6 provides a summary.

Table 6. General recommendation strategies for the lower Lake Chelan Watershed (The Watershed Company 2010).

Sub-basin	Habitat recommendation(s)
Manson Lakes	Implement grazing controls
	Improve fire control methods
	Eradicate and monitor for new invasive species infestations
	Implement habitat restoration projects
	Implement erosion protection projects
First Creek	Evaluate and reduce fuel load
	Improve fire control methods
	Encourage mature trees through restoration and protection
	Restore post-fire habitat
	Promote a rage of successional stages
	Eradicate and monitor for new invasive species infestations
	Reintroduce fire in low-fire regimes
Twenty-five Mile Creek	Improve fire control methods
	Reintroduce fire in low-fire regimes
	Restore degraded riparian areas
	Restore post-fire vegetation
	Improve upstream channel conditions
	Evaluate and reduce fuel load
	Promote a range of successional stages
	Encourage mature trees through restoration and protection
	Remove fish barriers
	Repair existing artificial spawning channel
	Eradicate and monitor for new invasive species infestations
Wapato Secondary	Reestablish lakefringe and aquatic wetlands
	Restore lakeshore vegetation
	Eradicate and monitor for new invasive species infestations

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