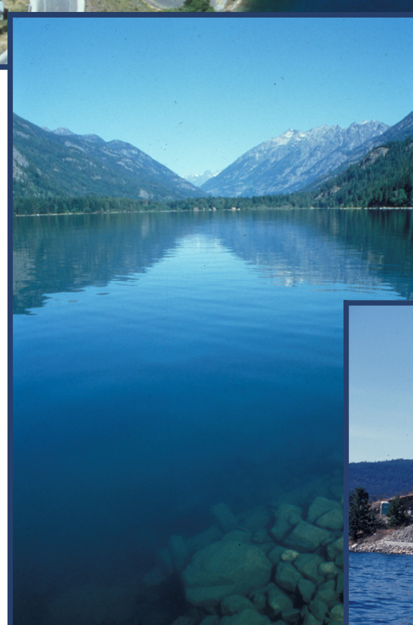
Phase II
Water Quantity Assessment
WRIA 47 (Lake Chelan)
December 2009



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WRIA47
Lake Chelan

Phase II
Water Quantity Assessment

Prepared By:

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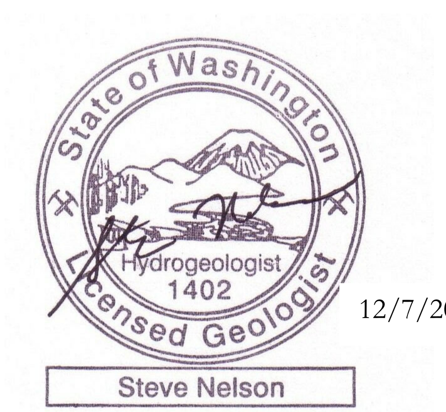
PLANNERS
SCIENTISTS



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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 85ºF, and the average winter minimum in Holden Village is 15ºF (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.

<u>Bedrock</u>
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.

<u>Glacial Deposits</u>
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.

3.1.1 Water Right Claim in WRIA 47

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.

3.1.2 Groundwater Claims in WRIA 47

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.

3.1.3 Surface Water Claims in WRIA 47

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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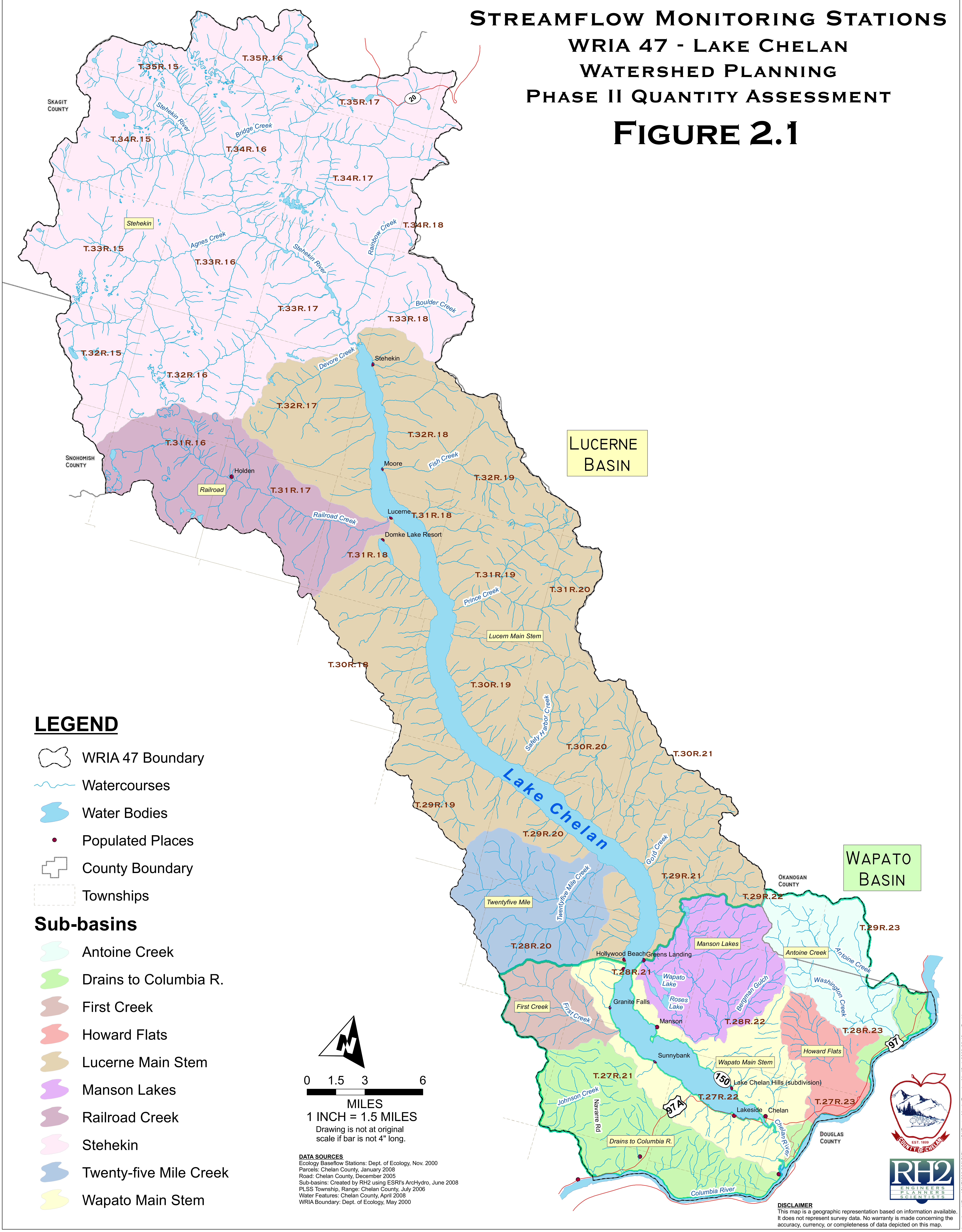
Streamflow Monitoring Stations
WRIA 47 - Lake Chelan
Watershed Planning
Phase II Quantity Assessment
Figure 2.1



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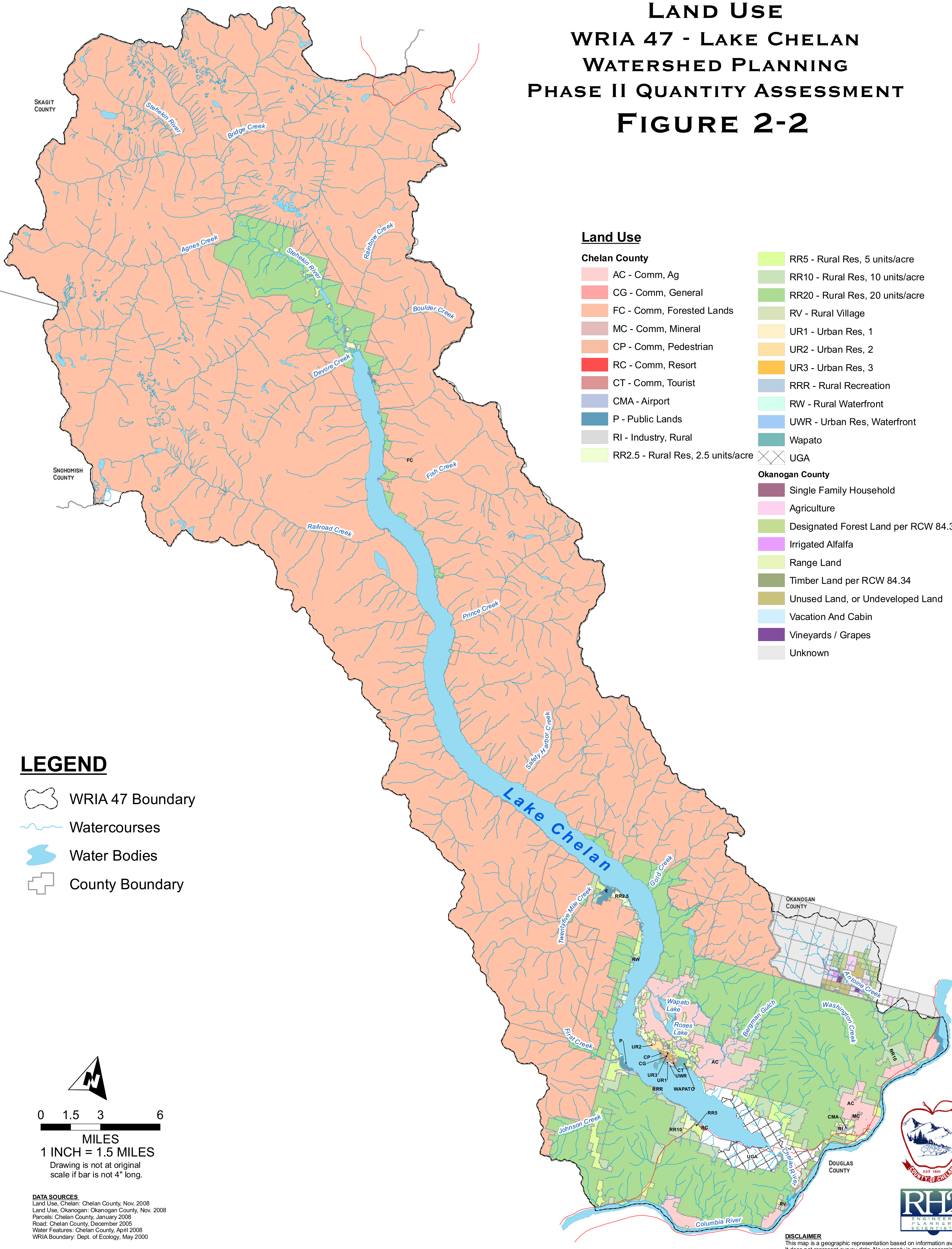
Land Use
WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment
Figure 2-2



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

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 2005
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2000

COUNTY OF CHELAN EST. 1899

RH2 ENGINEERS PLANNERS SCIENTISTS

DISCLAIMER
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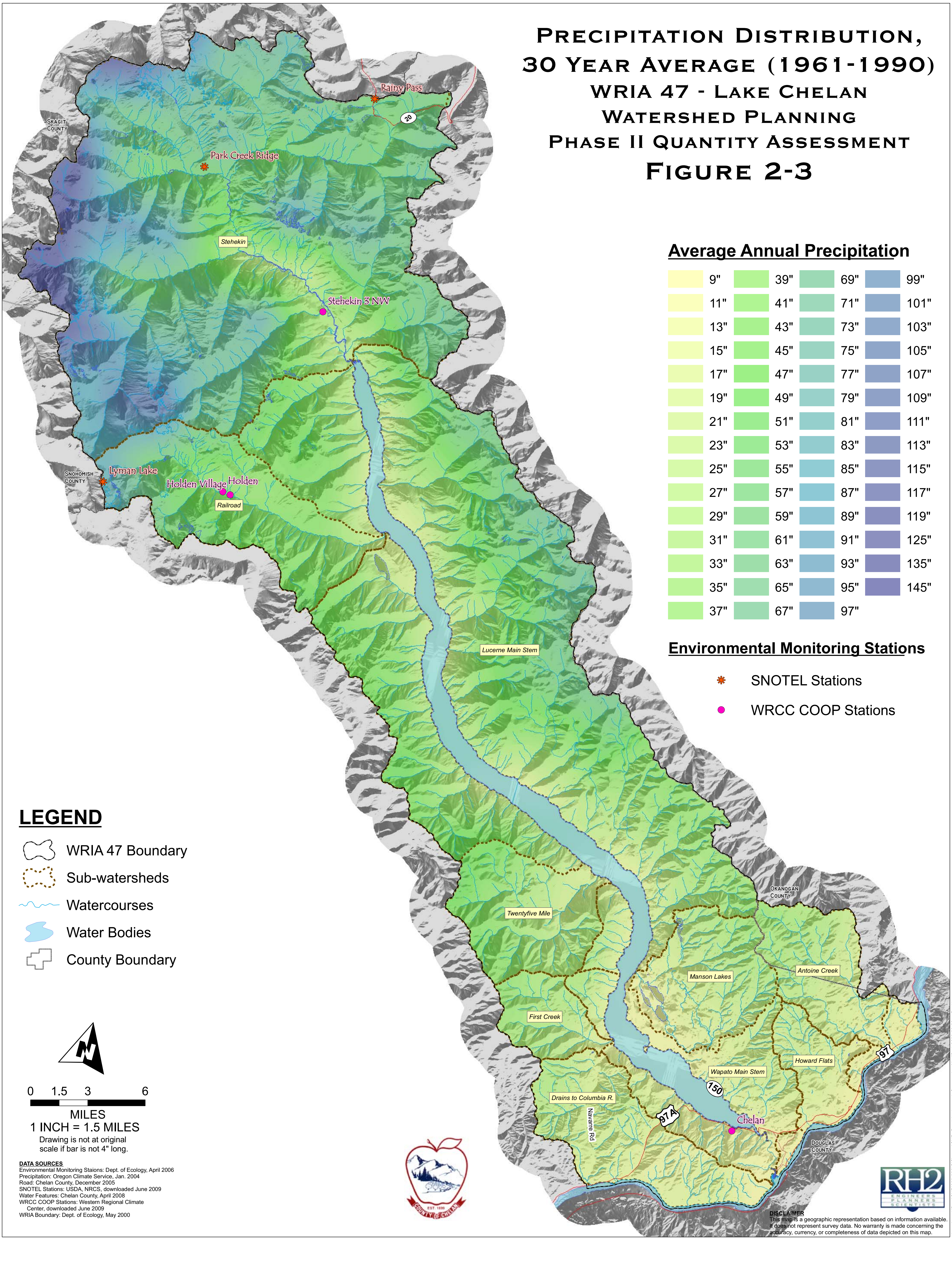

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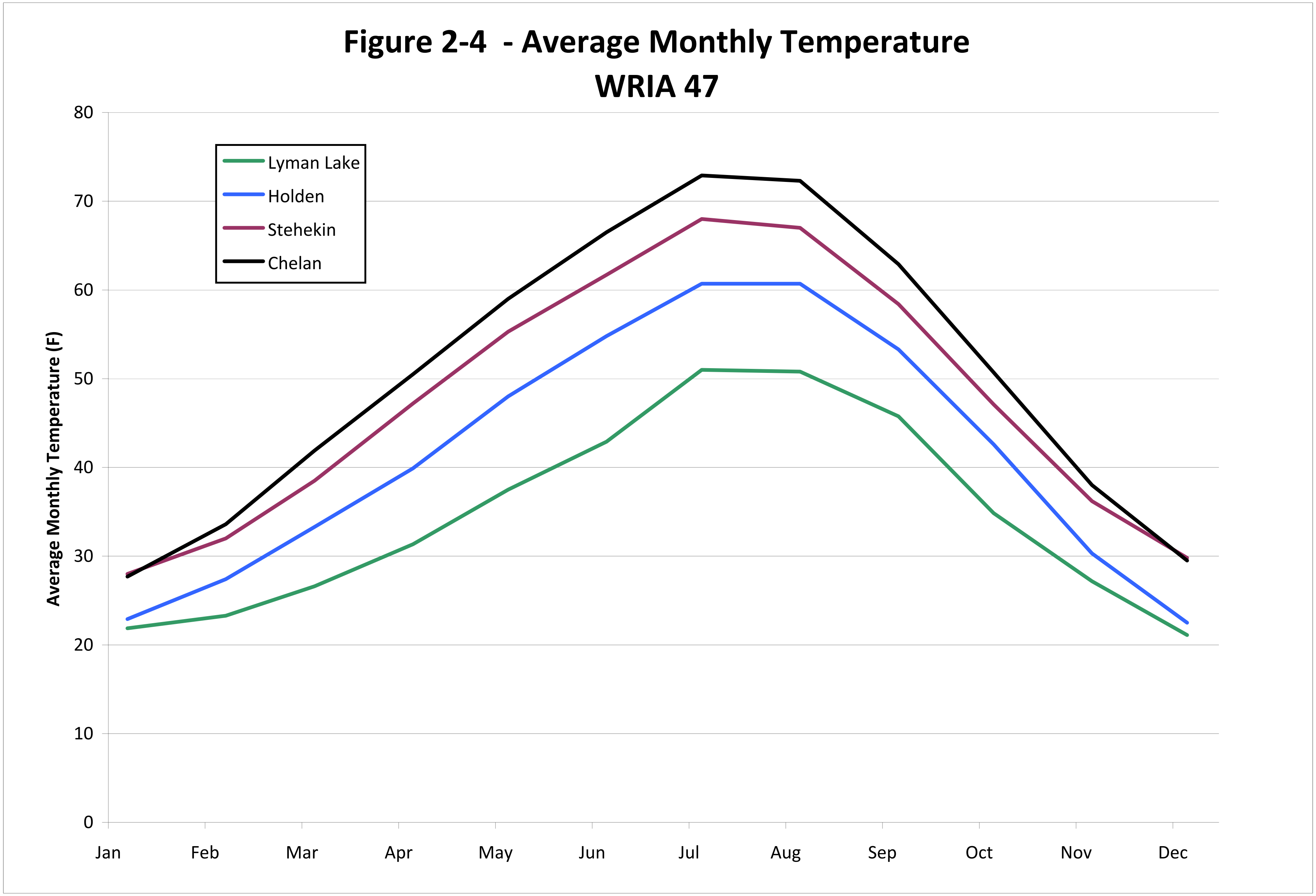


Figure 2-4 - Average Monthly Temperature
WRIA 47
Average Monthly Temperature (F)
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lyman Lake
Holden
Stehekin
Chelan

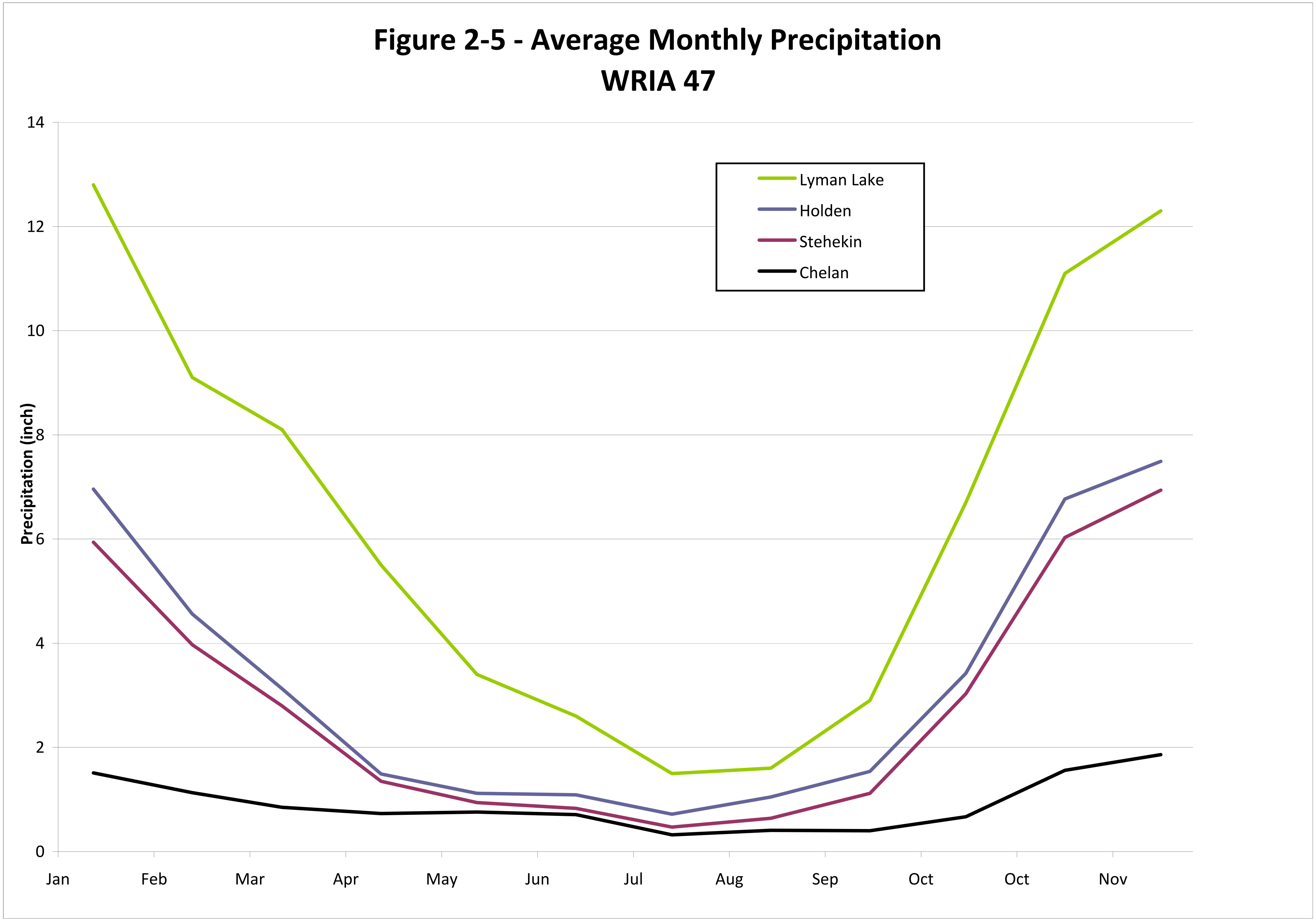


Figure 2-5 - Average Monthly Precipitation
WRIA 47
Precipitation (inch)
0
2
4
6
8
10
12
14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Oct
Nov
Lyman Lake
Holden
Stehekin
Chelan

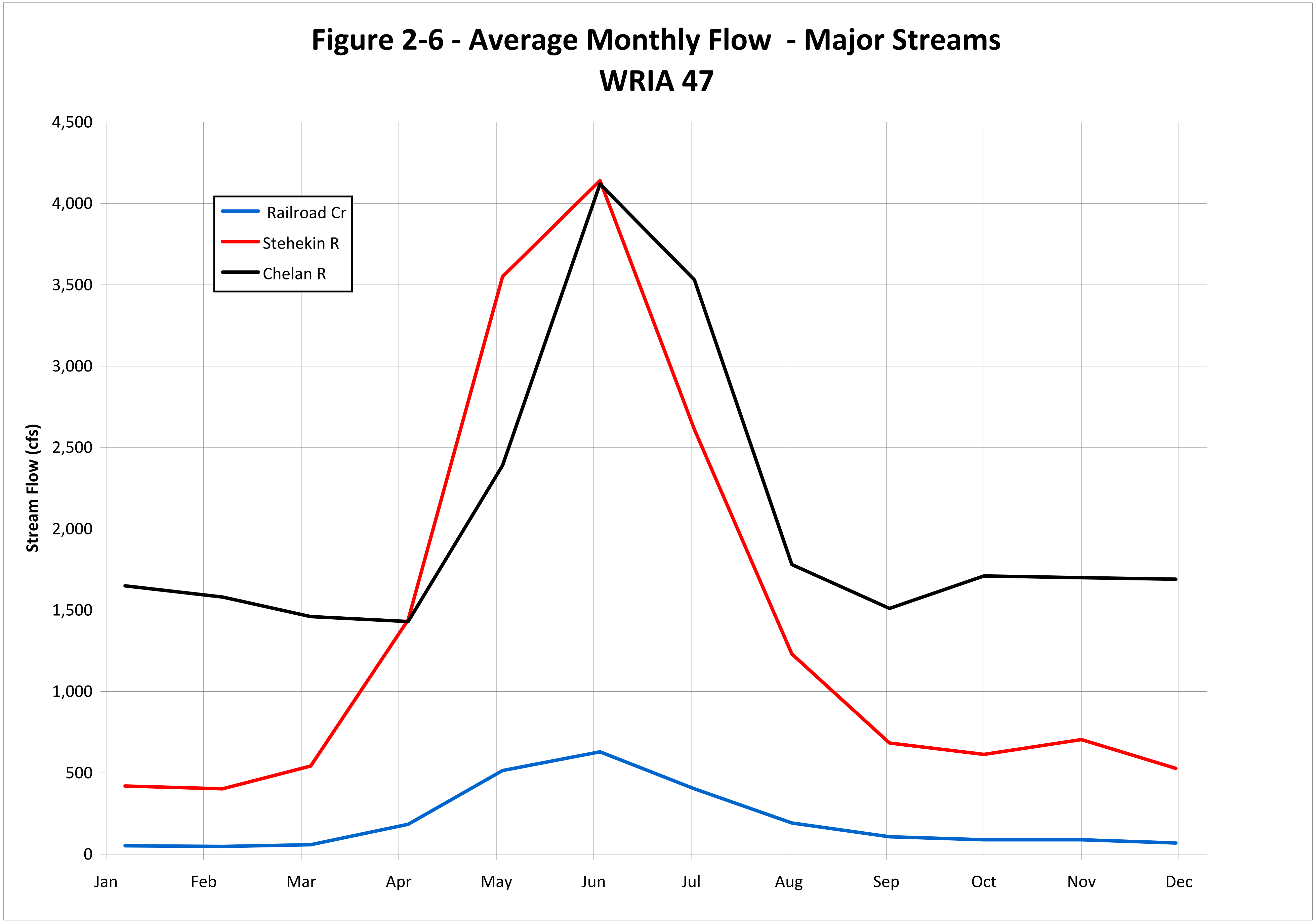


Figure 2-6 - Average Monthly Flow - Major Streams
WRIA 47
Railroad Cr
Stehekin R
Chelan R
Stream Flow (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 2-7 - Average Monthly Flow - Minor Streams
WRIA 47

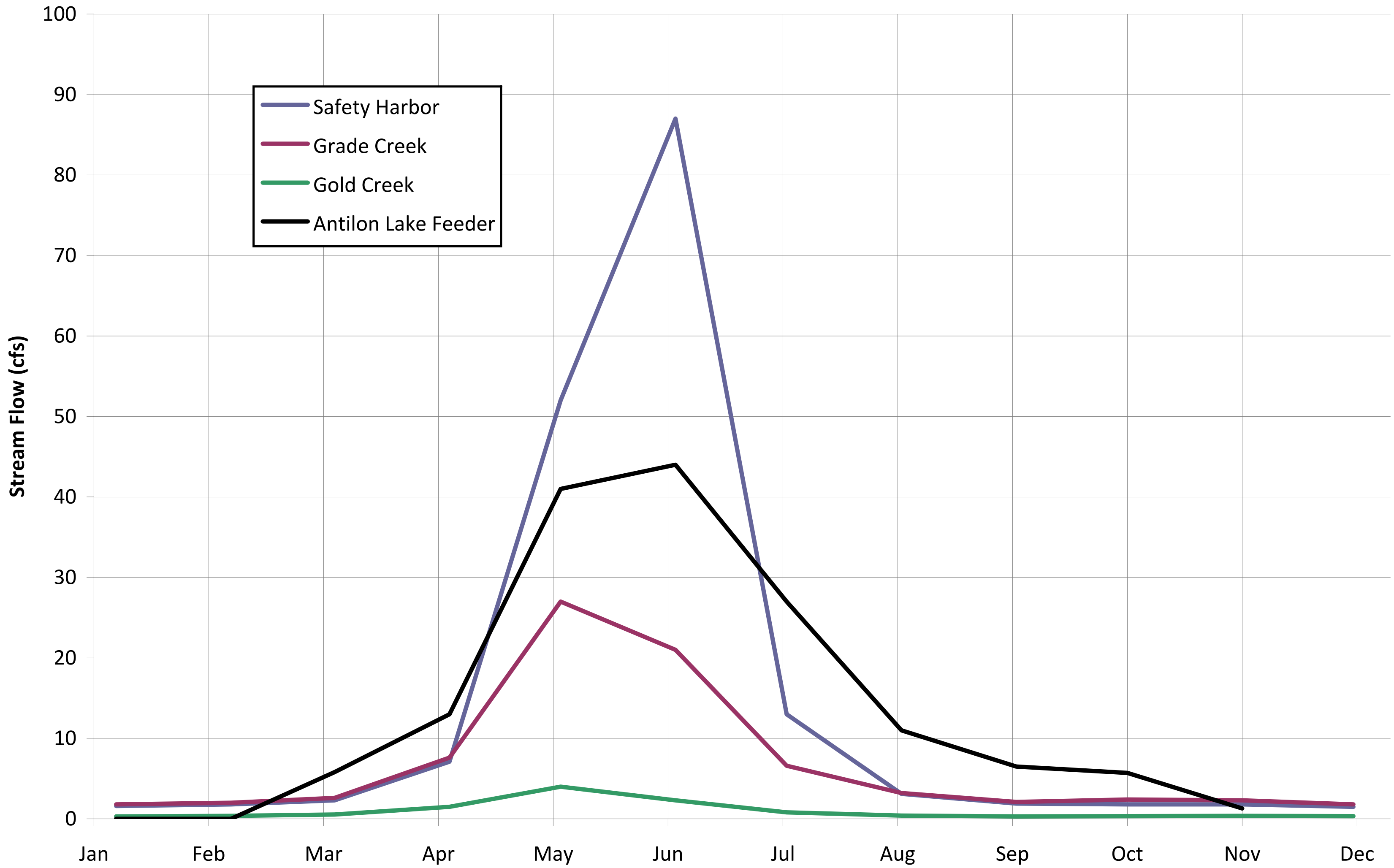
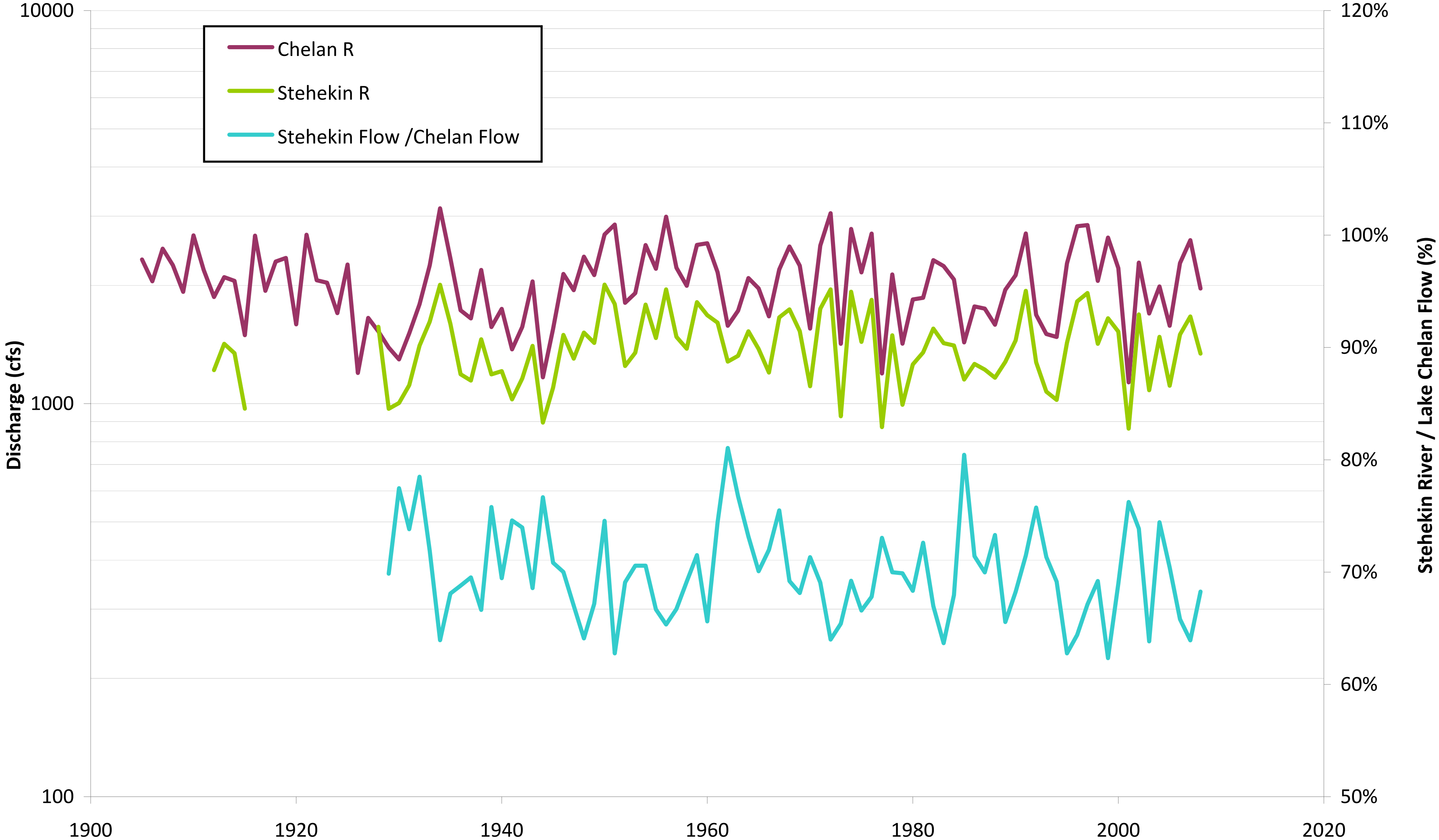


Figure 2-8 - Stehekin and Chelan River Flow
WRIA 47



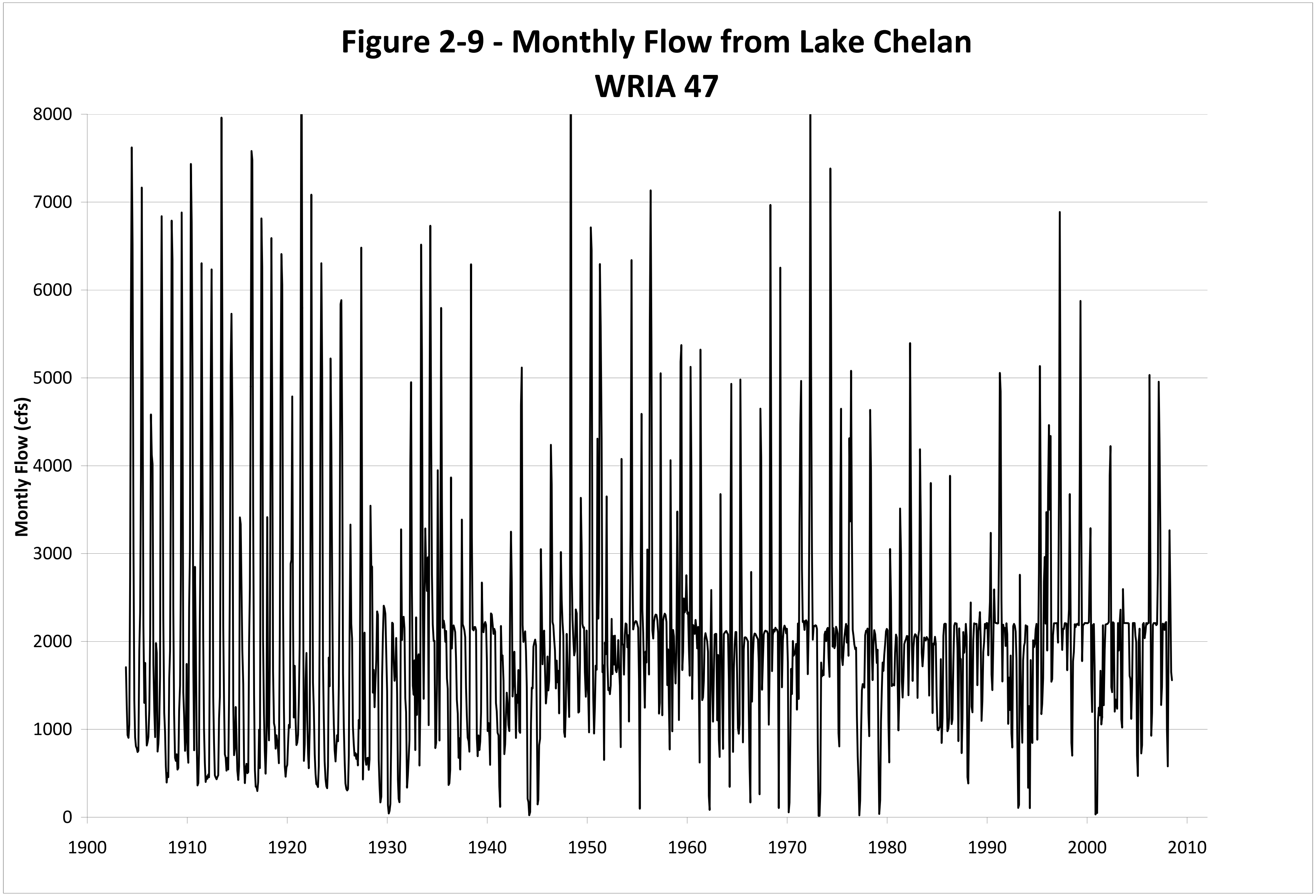


Figure 2-9 - Monthly Flow from Lake Chelan
WRIA 47
Montly Flow (cfs)
0
1000
2000
3000
4000
5000
6000
7000
8000
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

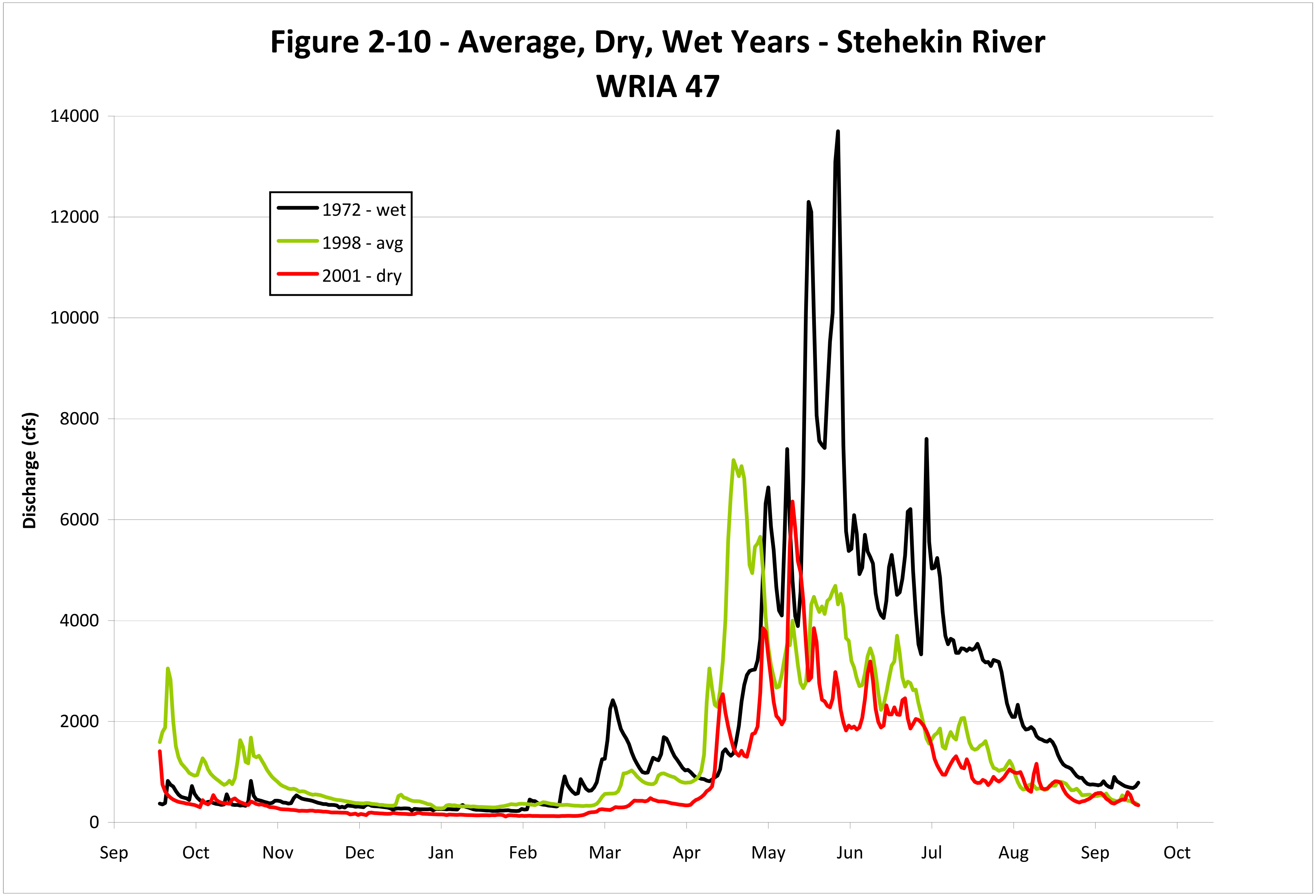


Figure 2-10 - Average, Dry, Wet Years - Stehekin River
WRIA 47
Discharge (cfs)
14000
12000
10000
8000
6000
4000
2000
0
1972 - wet
1998 - avg
2001 - dry
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

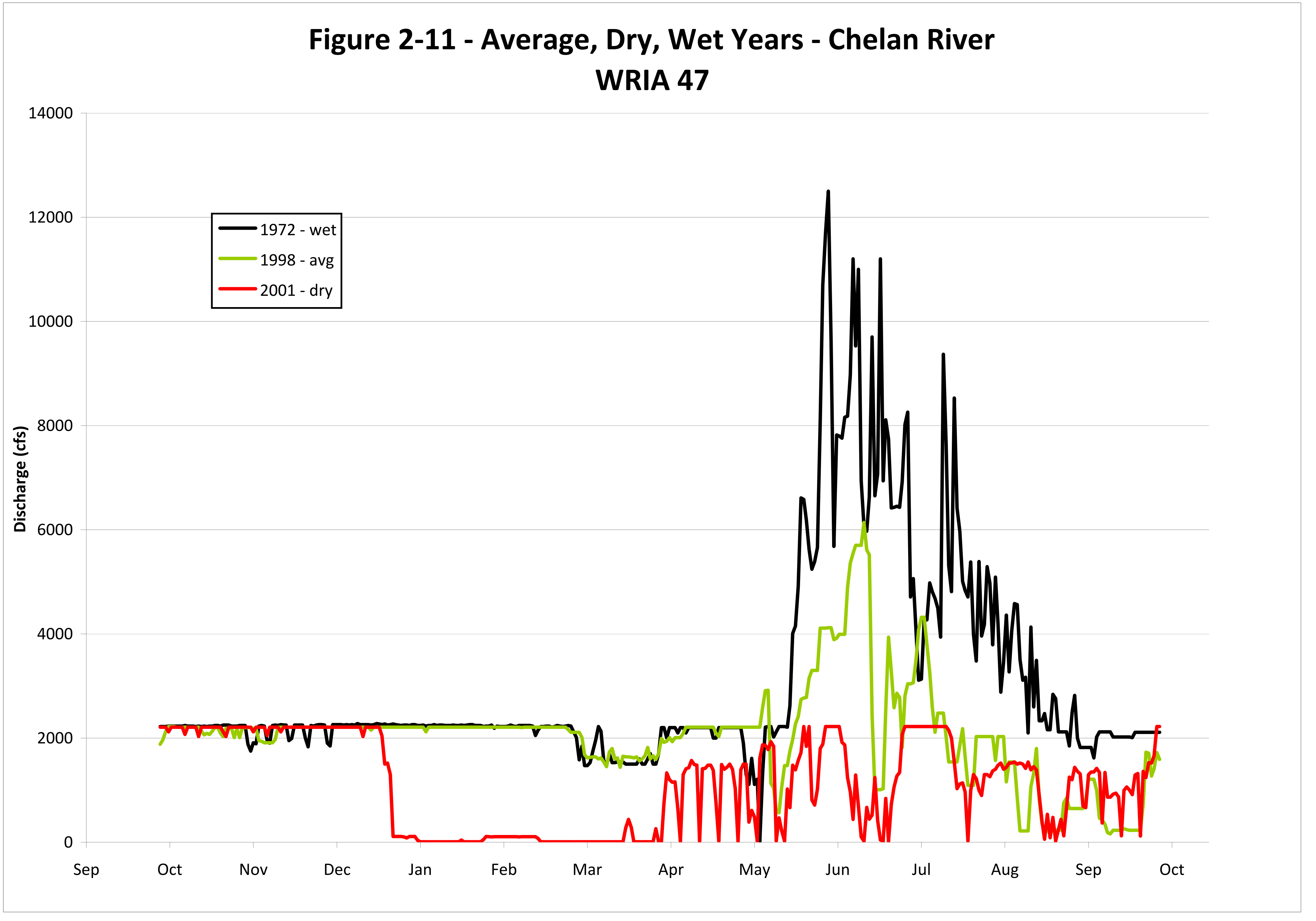
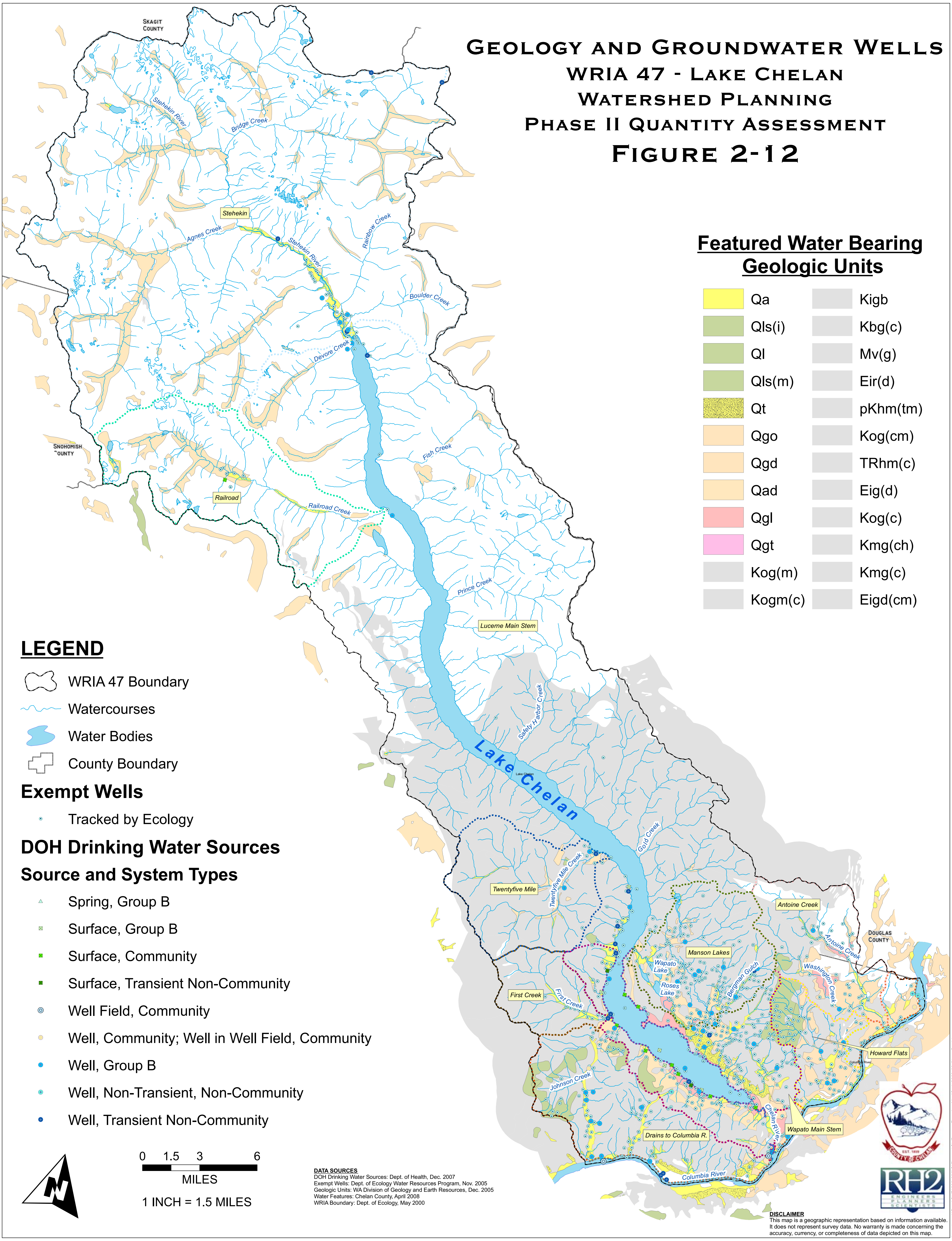


Figure 2-11 - Average, Dry, Wet Years - Chelan River
WRIA 47
Discharge (cfs)
14000
12000
10000
8000
6000
4000
2000
0
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1972 - wet
1998 - avg
2001 - dry


Geology and Groundwater Wells
WRIA 47 - Lake Chelan
Watershed Planning
Phase II Quantity Assessment
Figure 2-12
Featured Water Bearing Geologic Units
Qa
Qls(i)
Ql
Qls(m)
Qt
Qgo
Qgd
Qad
Qgl
Qgt
Kog(m)
Kogm(c)
Kigb
Kbg(c)
Mv(g)
Eir(d)
pKhm(tm)
Kog(cm)
TRhm(c)
Eig(d)
Kog(c)
Kmg(ch)
Kmg(c)
Eigd(cm)
LEGEND
WRIA 47 Boundary
Watercourses
Water Bodies
County Boundary
Exempt Wells
Tracked by Ecology
DOH Drinking Water Sources
Source and System Types
Spring, Group B
Surface, Group B
Surface, Community
Surface, Transient Non-Community
Well Field, Community
Well, Community; Well in Well Field, Community
Well, Group B
Well, Non-Transient, Non-Community
Well, Transient Non-Community
0 1.5 3 6
MILES
1 INCH = 1.5 MILES
Skagit County
Snohomish County
Douglas County
Stehekin
Stehekin River
Bridge Creek
Agnes Creek
Rainbow Creek
Boulder Creek
Devore Creek
Fish Creek
Railroad
Railroad Creek
Prince Creek
Lucerne Main Stem
Safety Harbor Creek
Lake Chelan
Gold Creek
Twentyfive Mile
Twentyfive Mile Creek
Antoine Creek
Antoine Creek
Manson Lakes
Wapato Lake
Roses Lake
Bergman Gulch
Washington Creek
First Creek
First Creek
Howard Flats
Johnson Creek
Chelan River
Wapato Main Stem
Drains to Columbia R.
Columbia River
DATA SOURCES
DOH Drinking Water Sources: Dept. of Health, Dec. 2007
Exempt Wells: Dept. of Ecology Water Resources Program, Nov. 2005
Geologic Units: WA Division of Geology and Earth Resources, Dec. 2005
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2000
COUNTY OF CHELAN
EST. 1899
RH2
ENGINEERS
PLANNERS
SCIENTISTS
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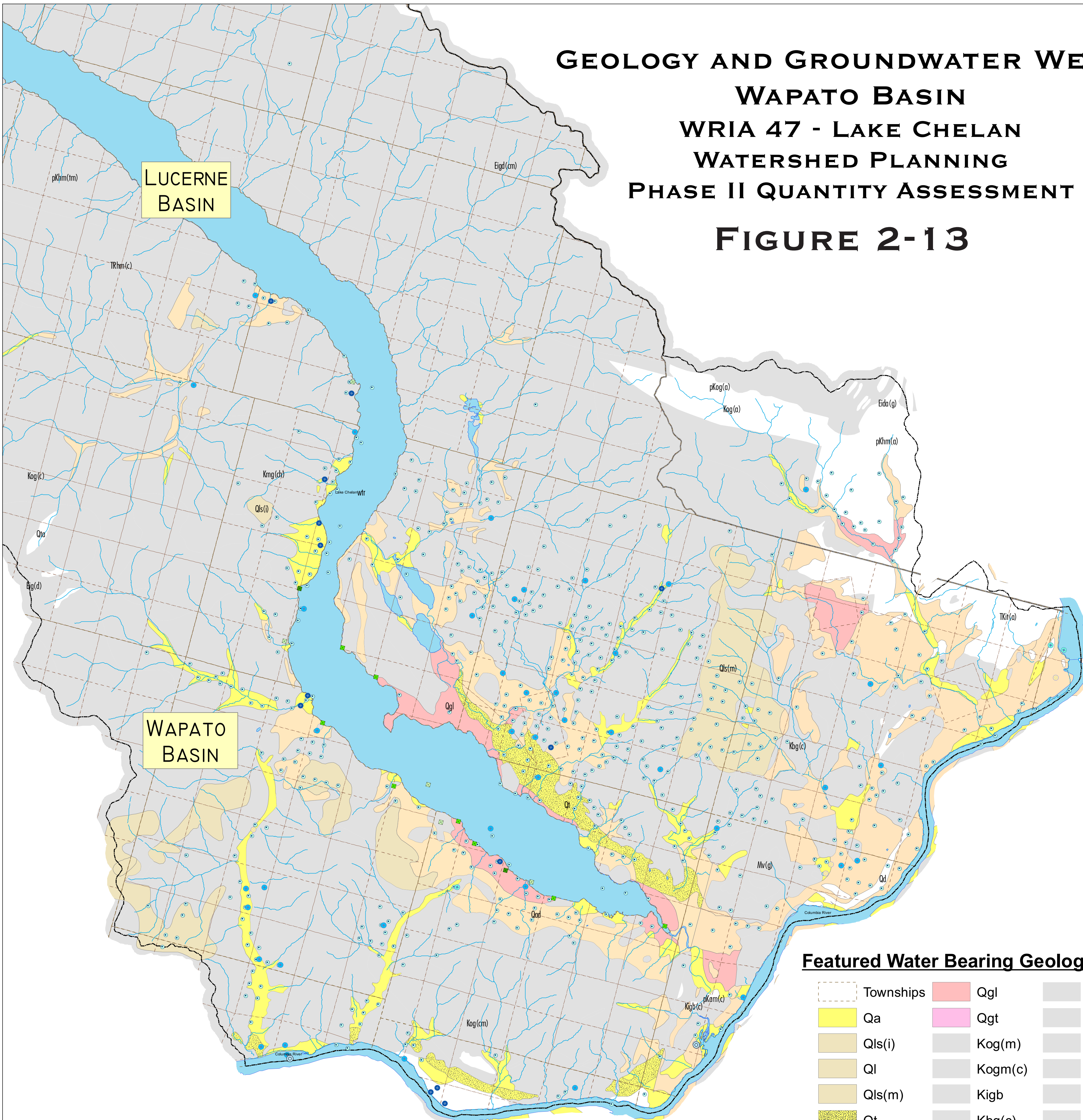
Geology and Groundwater Wells
Wapato Basin
WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment
Figure 2-13



Featured Water Bearing Geologic Units

Townships	Qgl	Kog(cm)
Qa	Qgt	TRhm(c)
Qls(i)	Kog(m)	Eig(d)
Ql	Kogm(c)	Kog(c)
Qls(m)	Kigb	Kmg(ch)
Qt	Kbg(c)	Kmg(c)
Qgo	Mv(g)	Eigd(cm)
Qgd	Eir(d)	
Qad	pKhm(tm)	

LEGEND

WRIA 47 Boundary
Watercourses
Water Bodies
County Boundary

Exempt Wells

Tracked by Ecology

DOH Drinking Water Sources

Source and System Types

Spring, Group B
Surface, Group B
Surface, Community
Surface, Transient Non-Community
Well Field, Community
Well, Community; Well in Well Field, Community
Well, Group B
Well, Non-Transient, Non-Community
Well, Transient Non-Community

0 0.75 1.5 3
MILES
1 INCH = 0.75 MILES

DATA SOURCES
DOH Drinking Water Sources: Dept. of Health, Dec. 2007
Exempt Wells: Dept. of Ecology Water Resources Program, Nov. 2005
Geologic Units: WA Division of Geology and Earth Resources, Dec. 2005
Water Features: Chelan County, April 2008
WRIA Boundary: Dept. of Ecology, May 2000

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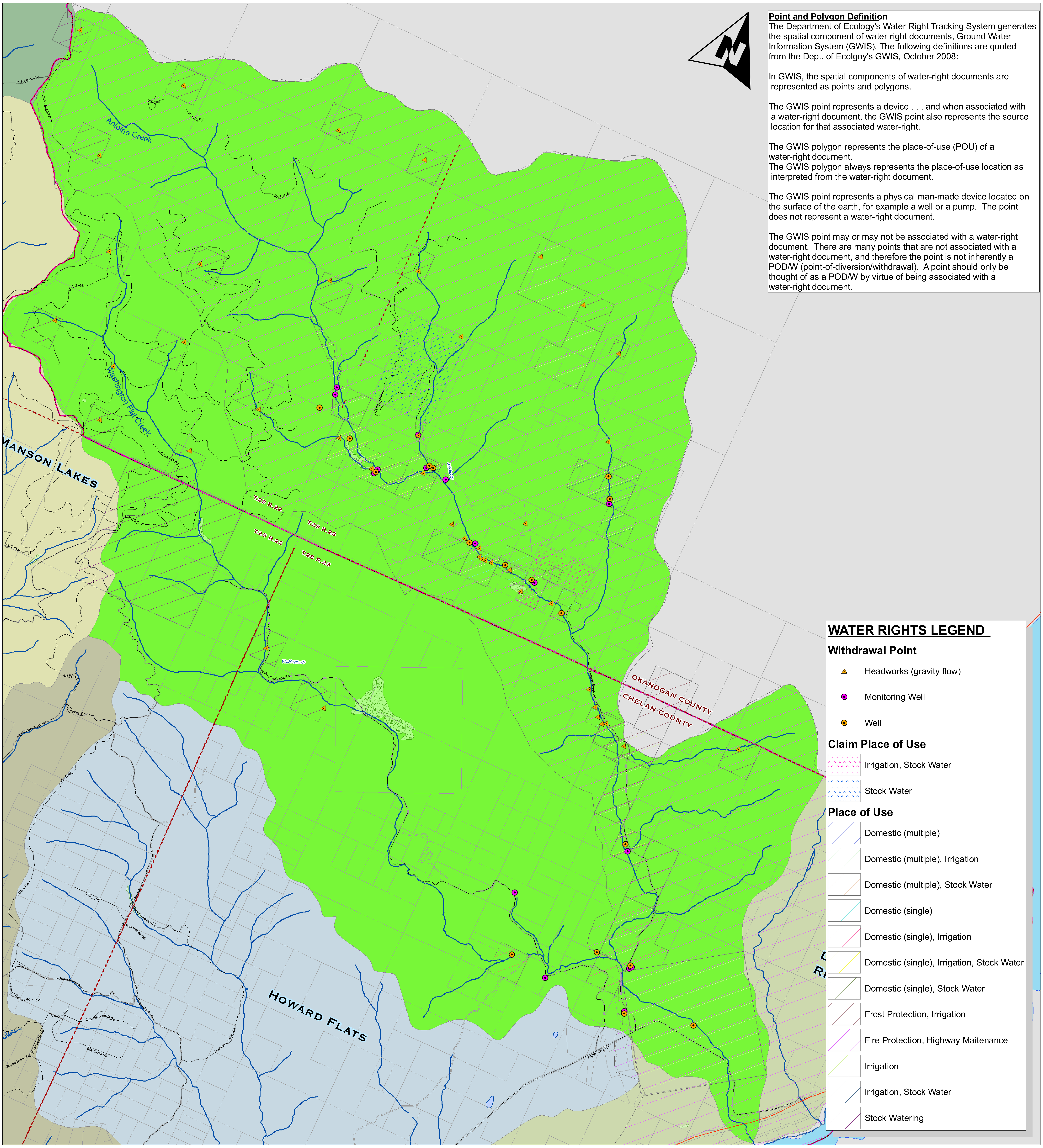

Figure 3-1. Antoine Creek Sub-Basin

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

WRIA 47 - Lake Chelan

Watershed Planning

Phase II Quantity Assessment

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

0 0.25 0.5 Miles

1 INCH = 0.25 MILES

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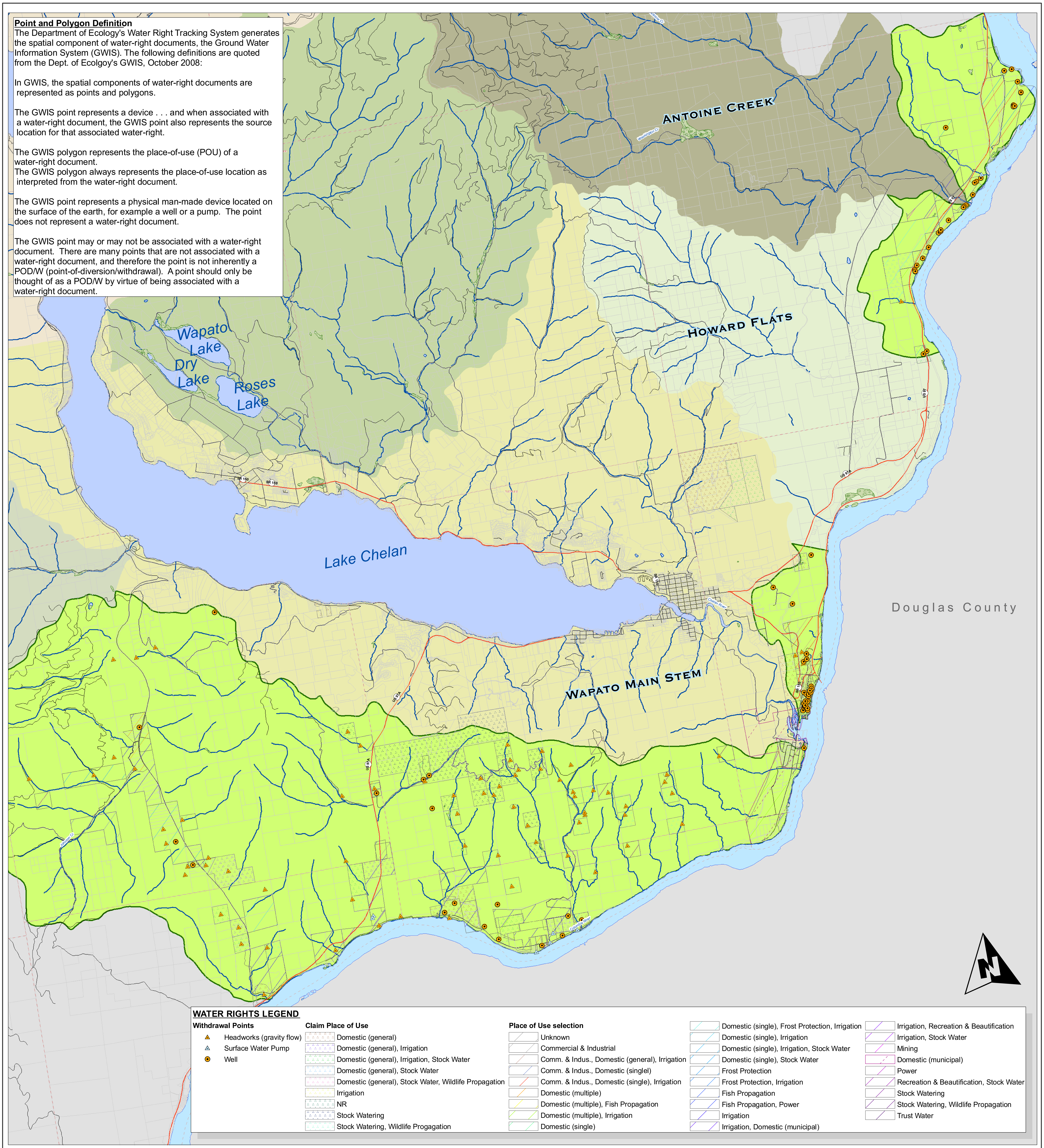


Figure 3-2. Direct Drainage to Columbia River

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

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.

LEGEND

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

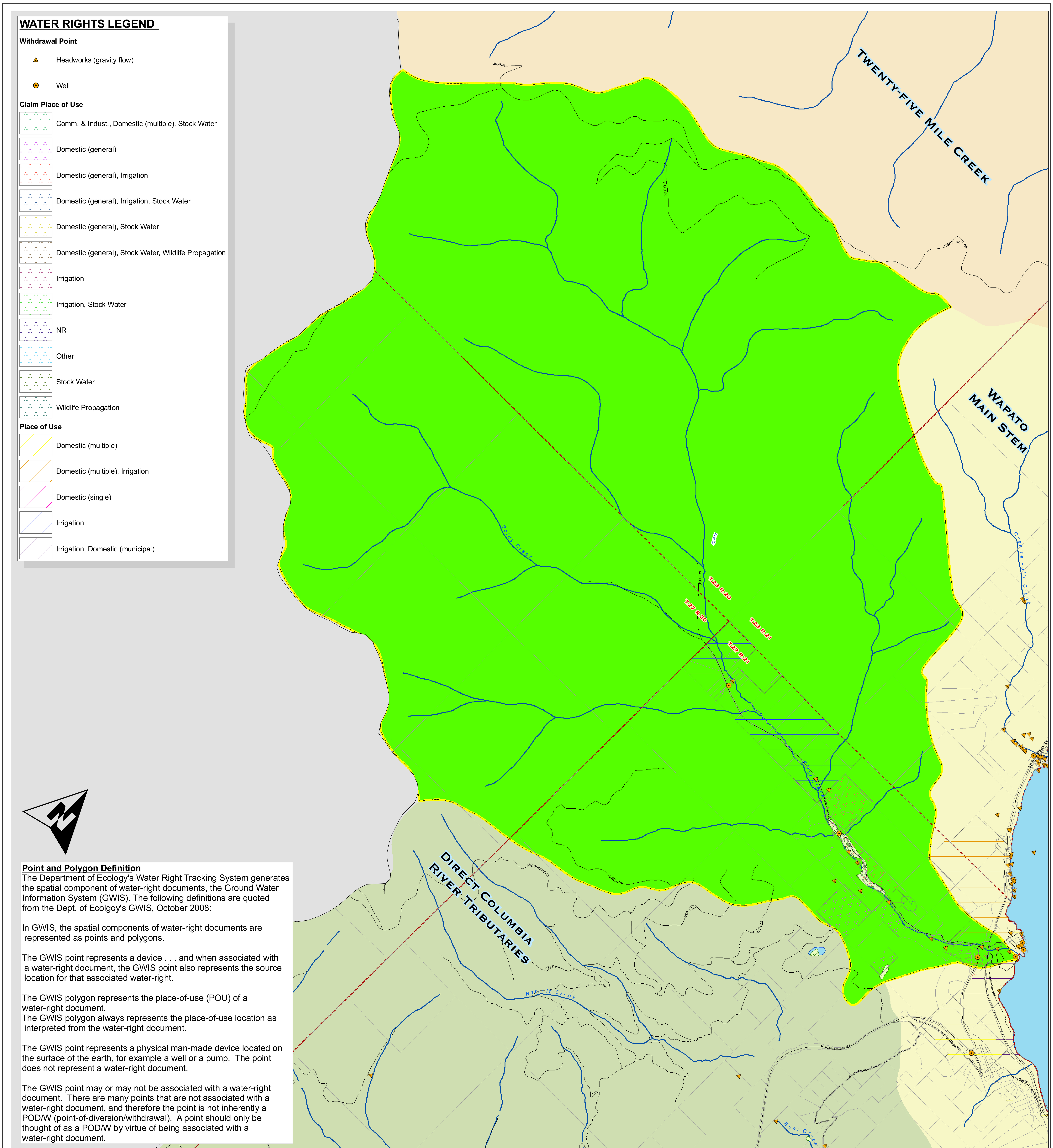


Figure 3-3. First Creek Sub-Basin

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

WRIA 47 - Lake Chelan Watershed Planning

Phase II Quantity Assessment

RH2 ENGINEERS PLANNERS SCIENTISTS

0 0.2 0.4 Miles

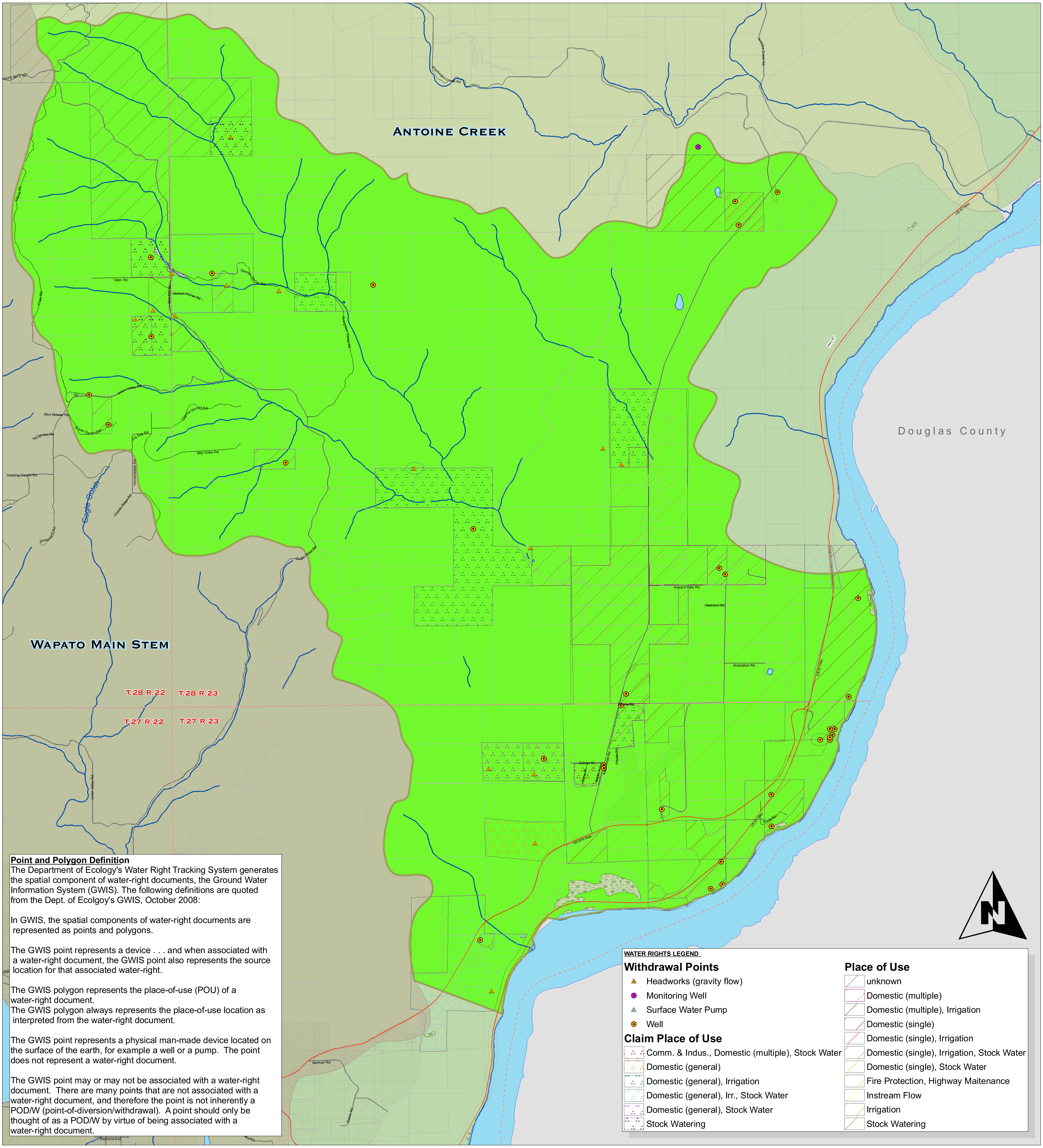
1 INCH = 1,056 Feet
1 INCH = 0.2 MILES

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.

LEGEND

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

J:\Data\CNR\208-086\GIS\maps\FirstCrk\First_Crk_CPOU_POU_PNT.mxd Modified by JDM, 02/20/09



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 3-4. Howard Flats Sub-Basin

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

WRIA 47 - Lake Chelan

Watershed Planning

Phase II Quantity Assessment

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

RH2 ENGINEERS PLANNERS SCIENTISTS

0 0.2 0.4 Miles

1 INCH = 0.2 MILES

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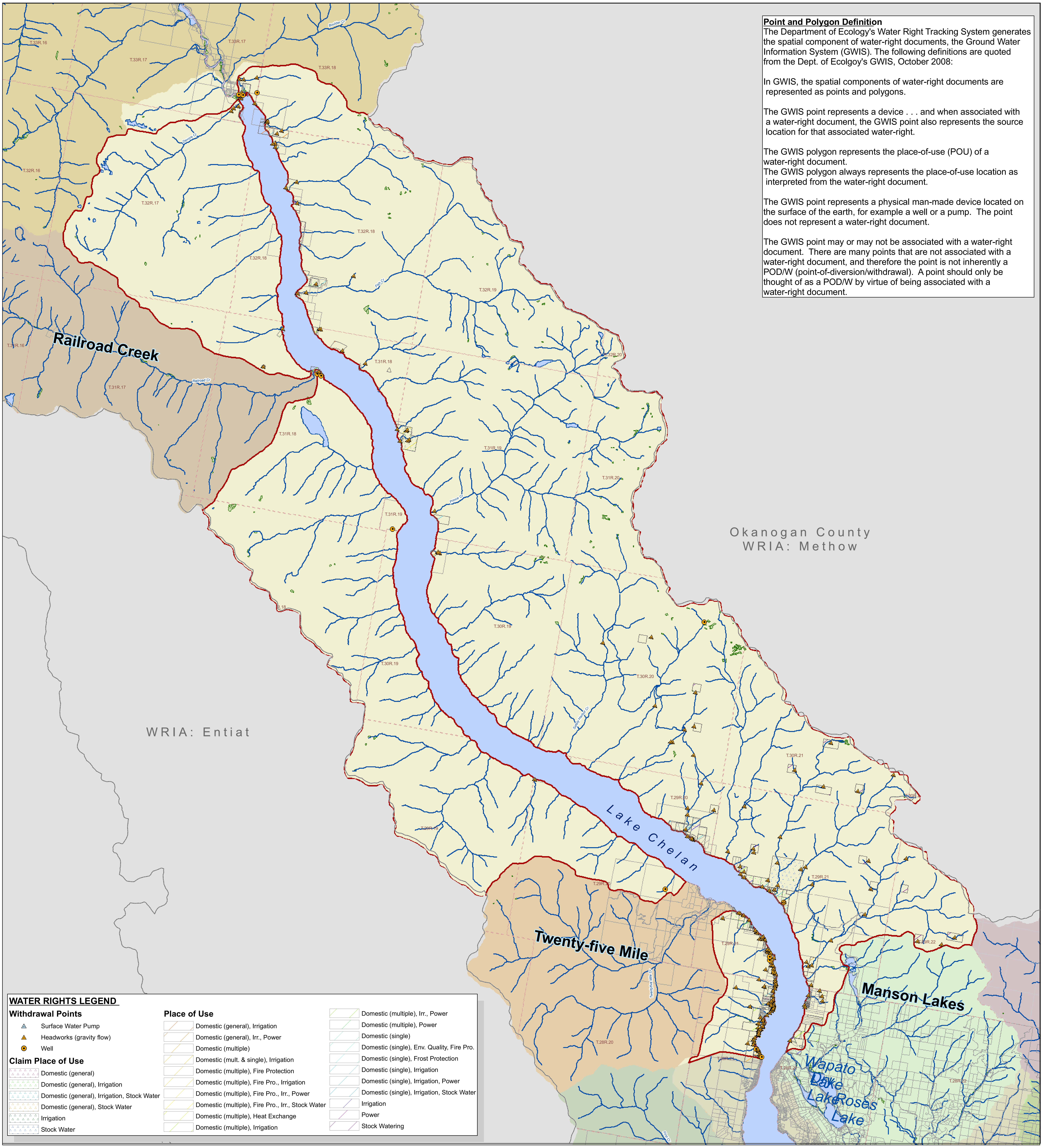

Figure 3-5. Lucerne Main Stem Sub-Basin

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

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

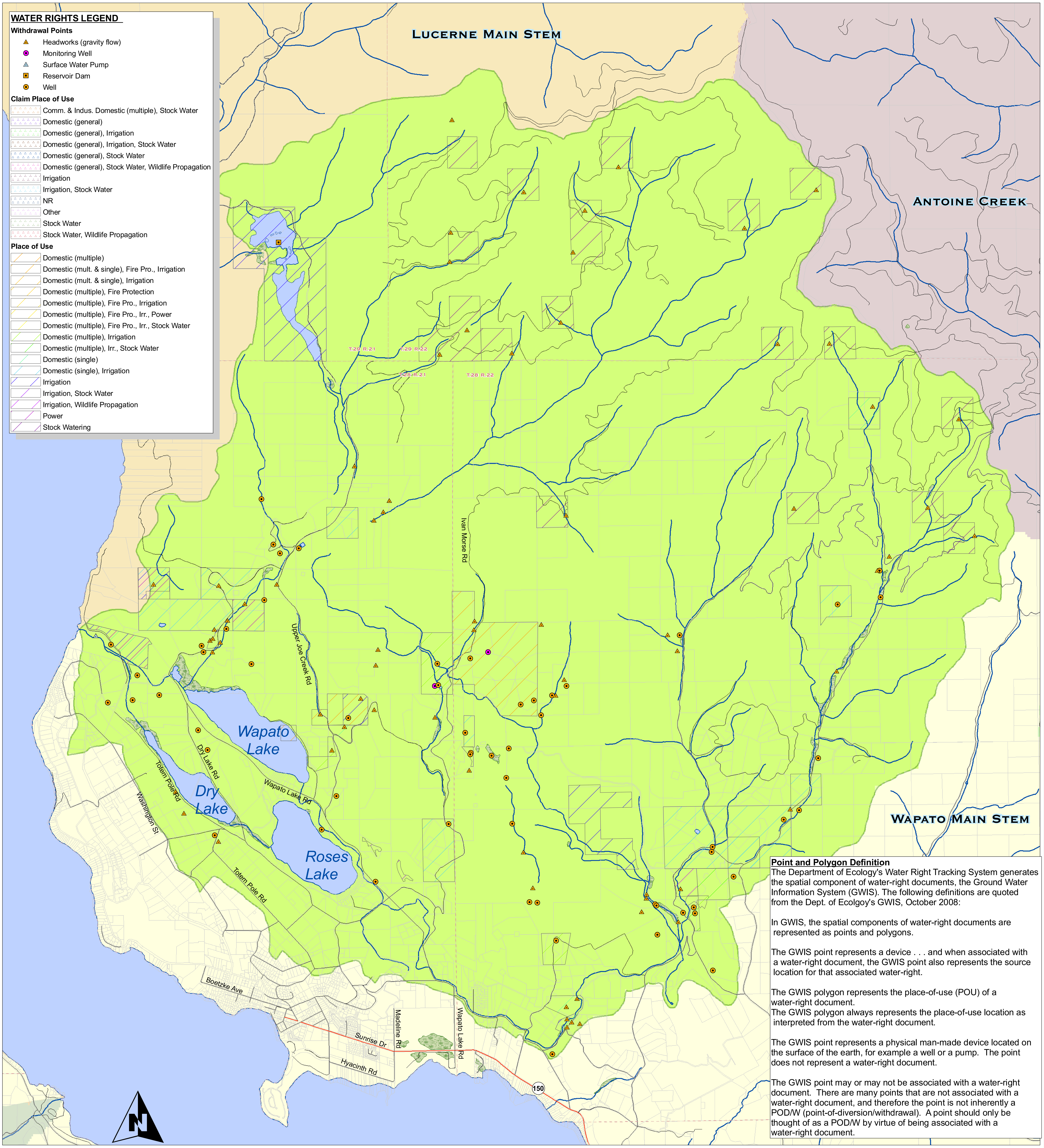
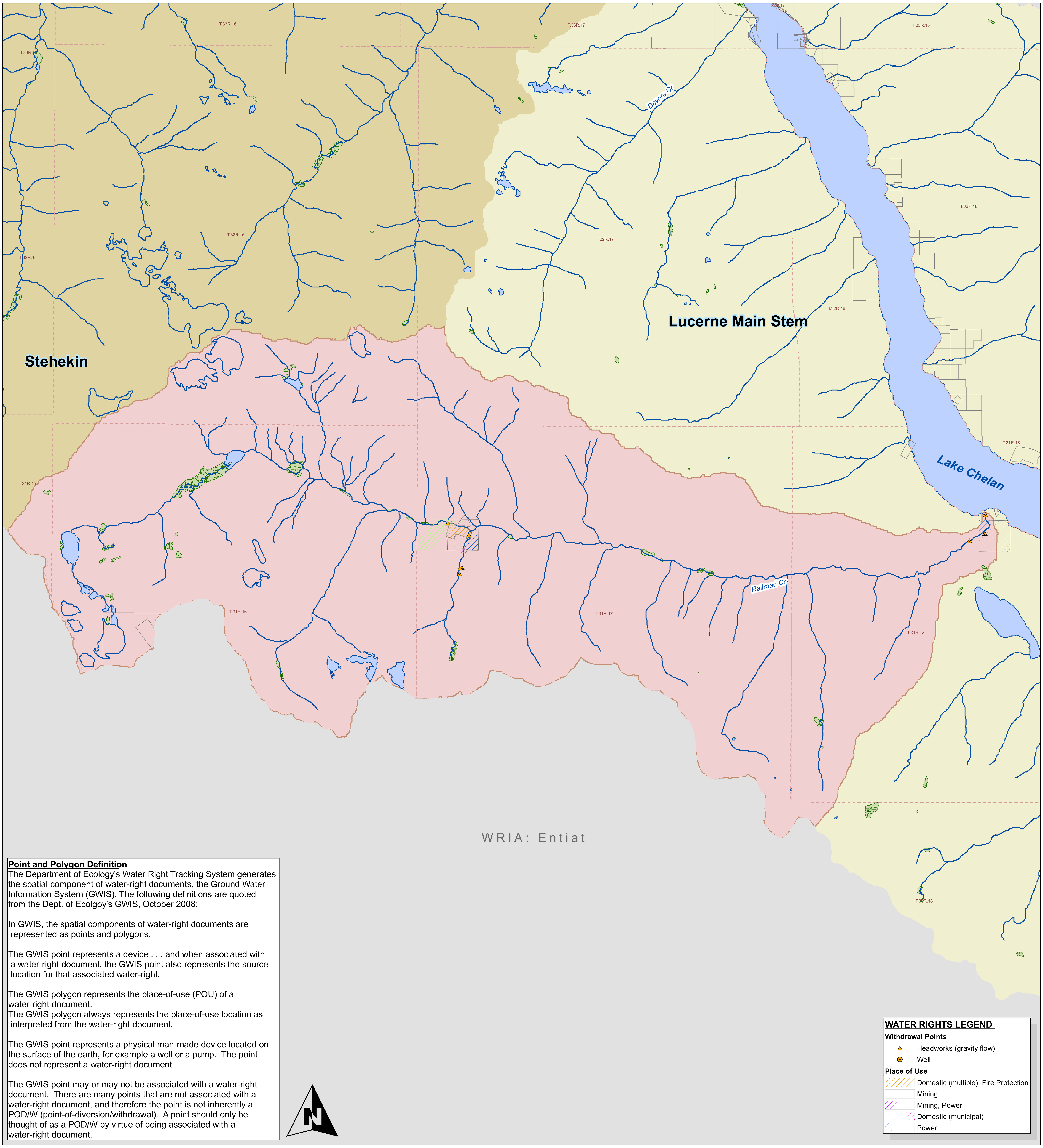


Figure 3-6. Manson Lakes Sub-Basin
Point of Withdrawals and Water-right Documents Listed Purpose
WRIA 47 - Lake Chelan
Watershed Planning
Phase II Quantity Assessment

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

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

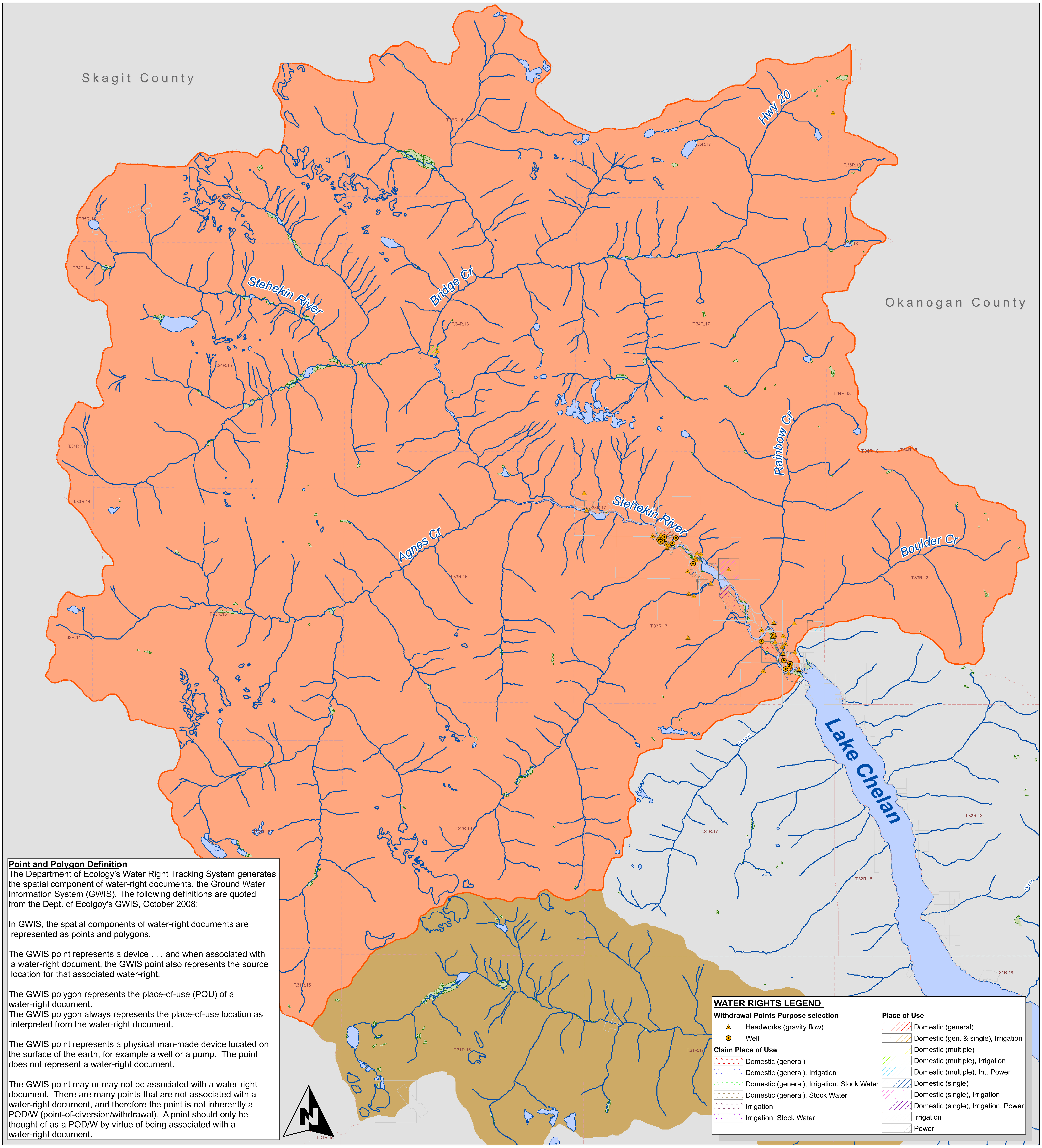
LEGEND

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

0 0.5 1 Miles

1 INCH = 0.5 MILES

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.



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:

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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

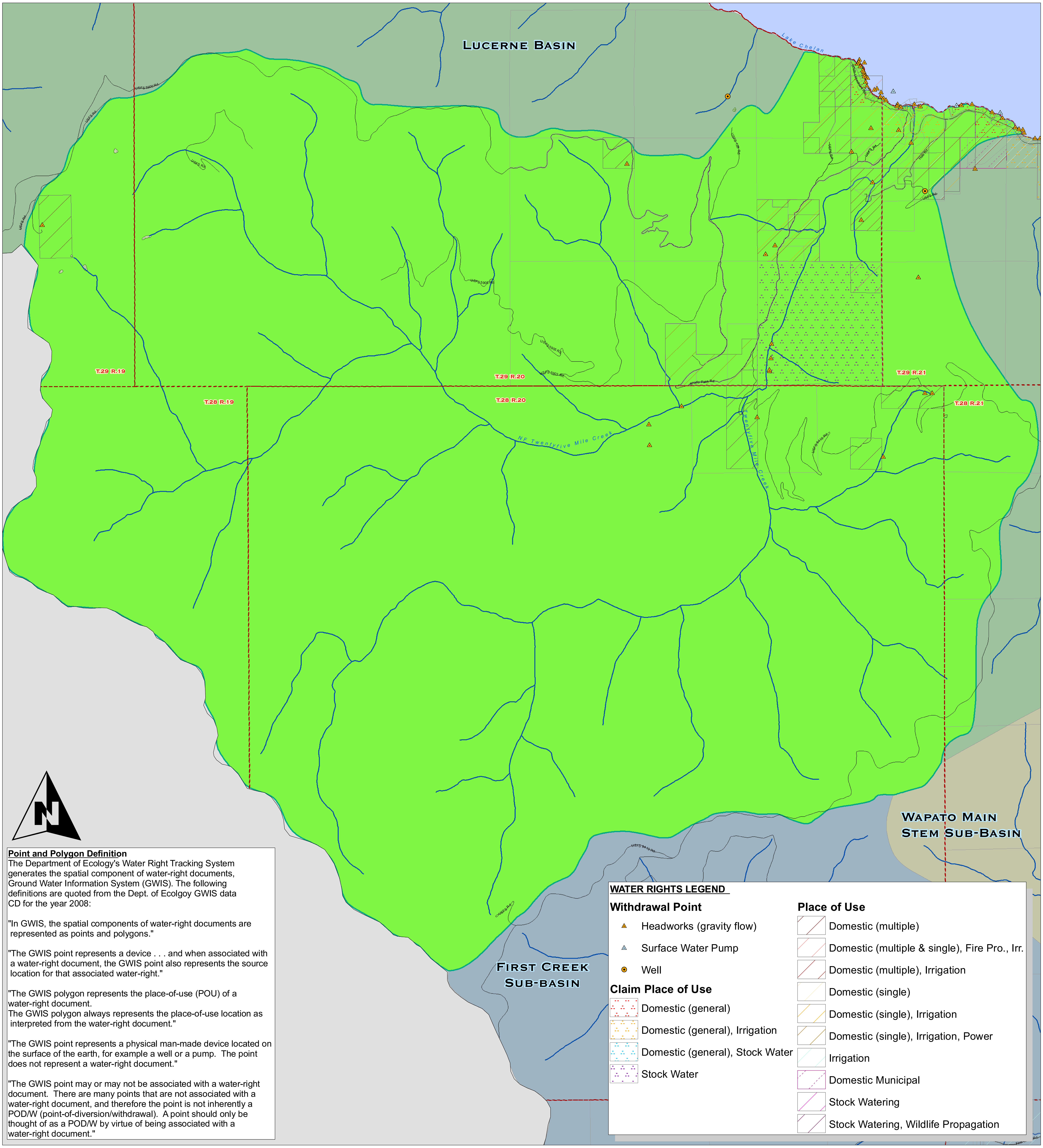
LEGEND

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

0 0.75 1.5 Miles

1 INCH = 0.75 MILES

Location: J:\Data\CNR\208-086\GIS\maps\Stehekin\Stehekin_CPOU_POU_pnt.mxd Revised: JDM on 12/29/08



Point and Polygon Definition

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

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

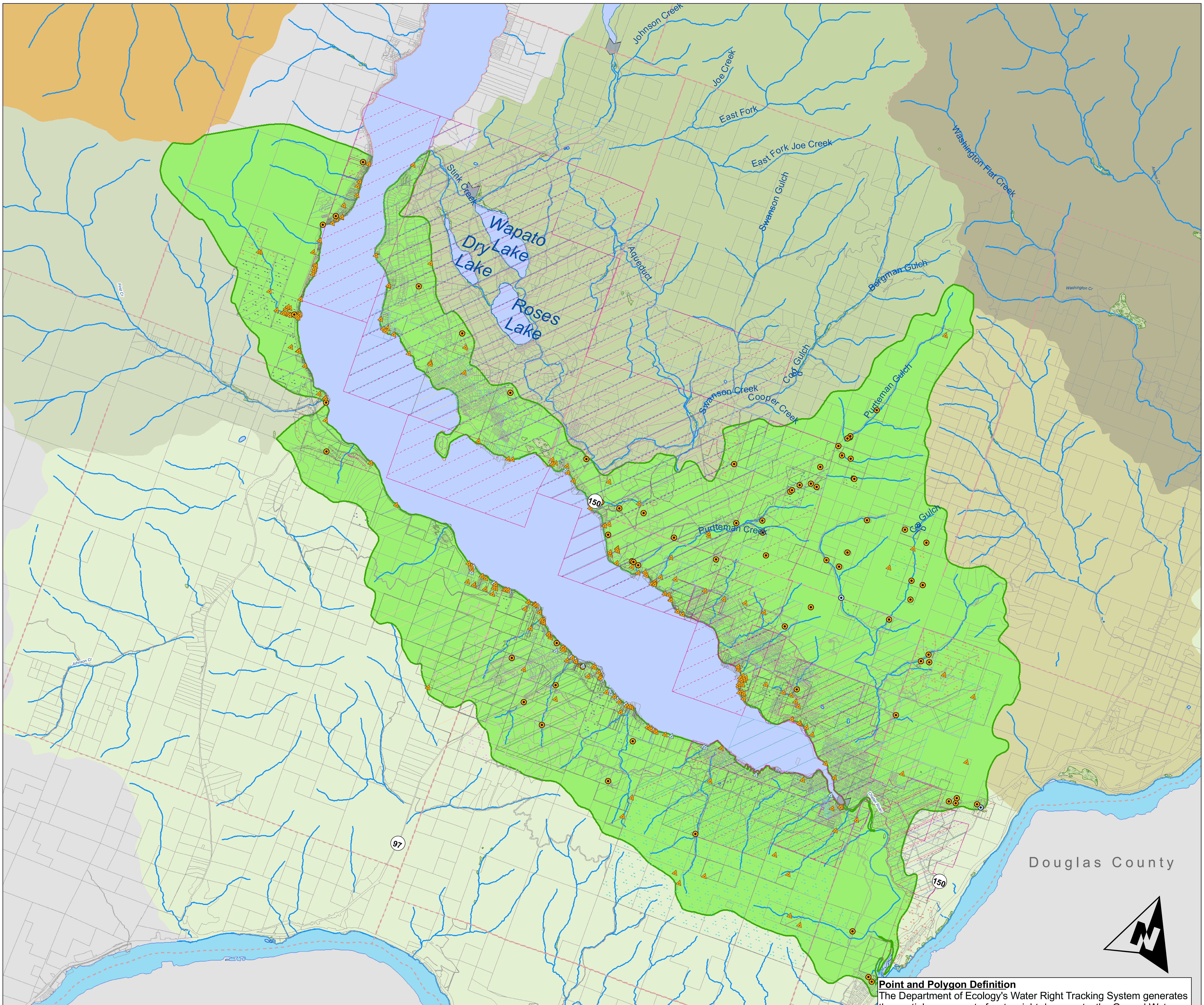
Phase II Quantity Assessment

LEGEND
Parcels
Township, Range
Roads
Highways
Water Courses
Waterbodies
Wetlands

0 0.25 0.5 Miles

1 INCH = 0.25 MILES
1 INCH = 1,320 FEET

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.



WATER RIGHTS LEGEND

Withdrawal Points
- Ground Water Collector
- Headworks (gravity flow)
- Surface Water Pump
- Well

Claim Place of Use
- Domestic (general)
- Domestic (general), Irrigation
- Domestic (general), Irrigation, Stock Water
- Domestic (general), Stock Water
- Domestic (general), Stock Water WL
- Irrigation
- Irrigation, Stock Water
- NR
- Other
- Stock Water
- Stock Water, Wildlife Propagation

Place of Use
- Comm., Indus., Domestic (multiple)
- Comm., Indus., Domestic (multiple), Frost Pro., Irrigation
- Comm., Indus., Domestic (single)
- Comm., Indus., Domestic (single), Irrigation
- Domestic (general)
- Domestic (general), Frost Protection, Irrigation, Rec,. Stock Water
- Comm., Indus., Domestic (general), Irrigation
- Comm., Indus., Domestic (general), Irrigation, Stock Water
- Domestic (multiple)
- Domestic (multiple), Frost Pro., Irrigation
- Domestic (multiple), Frost Pro., Irrigation, Stock Water
- Domestic (multiple), Irrigation
- Domestic (multiple), Irrigation, Stock Water
- Domestic (multiple), Irrigation, Wildlife Propagation
- Domestic (multiple), Recreation
- Domestic (multiple), Stock Water
- Domestic (single)
- Domestic (single), Frost Protection
- Domestic (single), Fire Protection
- Domestic (single), Irrigation
- Domestic (single), Irrigation, Stock Water
- Fire Protection, Irrigation
- Irrigation
- Irrigation, Domestic (municipal)
- Irrigation, Stock Water
- Domestic (municipal)
- Power
- Stock Water
- Stock Water, Wildlife Propagation

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:

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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

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

0 0.5 1 Miles

1 INCH = 0.5 MILES

Location: J:\Data\CNR\208-086\GIS\maps\WapatoMS_CPOU_POU_PNT.mxd Modified by JDM on 12/04/08

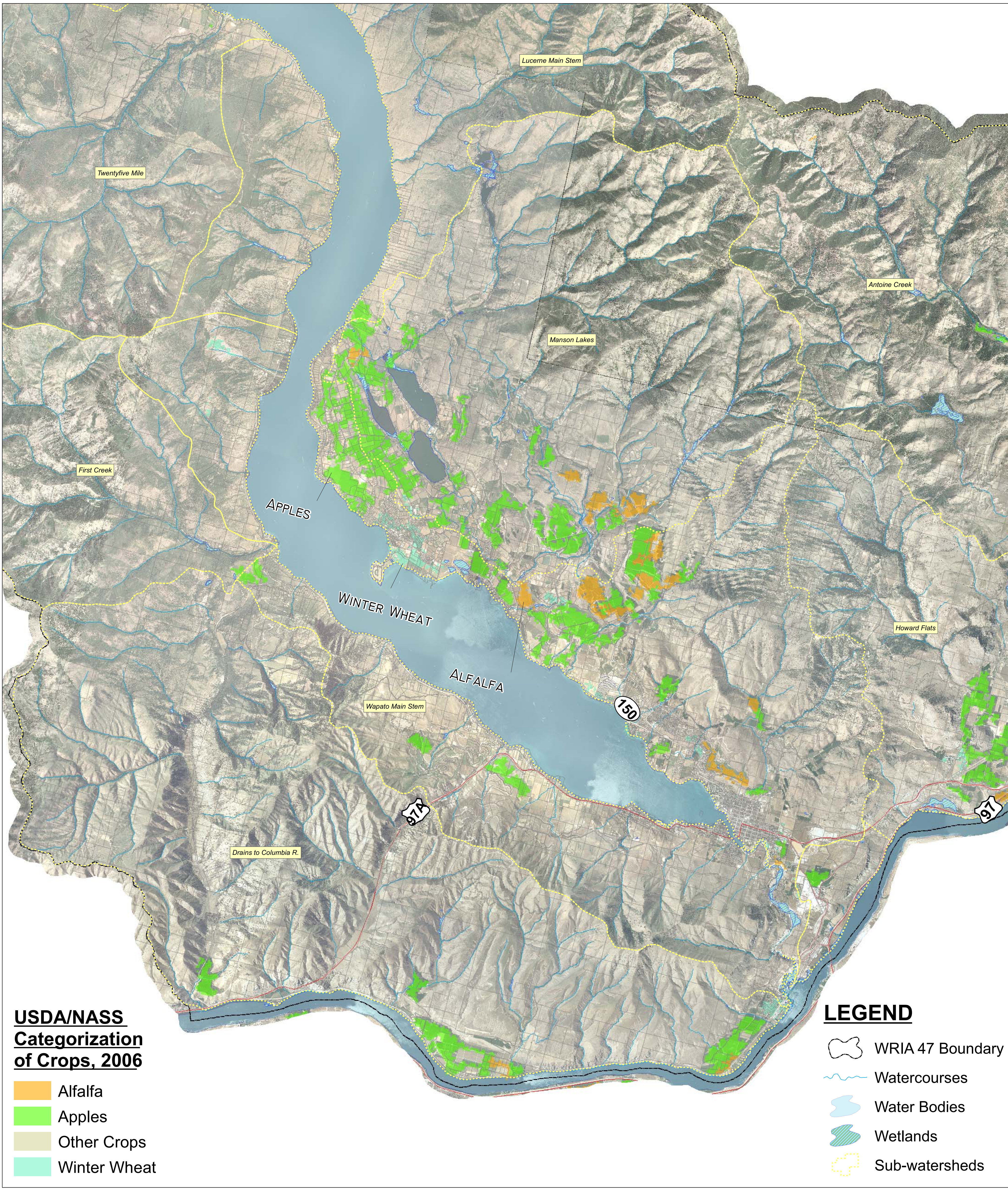
0 0.5 1 2
MILES
1 INCH = 0.5 MILES
Drawing is not at original scale if bar is not 4" long.

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

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 2005
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.

Location: J:\Data\CNR\208-086\GIS\maps\CNR_Municipal_E.mxd Modified: 2009-06-24 By: jdm



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
Crop Cover: USDA, National Agricultural Statistics Service (NASS), Research and Development Division, March 2007
Road: Chelan County, December 2005
Water Features: Chelan County, April 2008
Wetlands: US Fish and Wildlife Service's National Wetlands Inventory, Oct. 1998
WRIA Boundary: Dept. of Ecology, May 2000

Figure 4-2. Crop Cover
WRIA 47 - Lake Chelan Watershed Planning Phase II Quantity Assessment

DISCLAIMER
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Location: J:\Data\CNR\208-086\GIS\maps\CNR_CropCvr.mxd Modified: 2009-06-24 By: jdm

Figure 5-1
Water Balance Schematic